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AN EXAMINATION OF CROSS-MODAL TRANSFER IN HEARING AND HEARING-IMPAIRED CHILDREN

by

© BARBARA KLEIN

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "An Examination of Cross-Modal Transfer in Hearing and Hearing-Impaired Children," submitted by Barbara Klein in partial fulfilment of the requirements for the degree of Master of Education in Educational Psychology.

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Date August 31, 1973

ABSTRACT

It was hypothesized than an inability to perceive auditory stimuli is cause for difficulty in perceptual processing of certain sensory information. Sixty-six hearing impaired and normal-hearing subjects were tested on intra-modal, intra-condition, cross-modal and cross-condition transfer problems. Mean total correct responses to the problems were compared between and within the groups of normal hearing and hearing-impaired subjects. Hearing subjects produced significantly more correct responses than deaf subjects on cross-modal and modality-incongruent tasks. As expected, no differences between groups were found when tasks involved stimulus distributions in which both groups were equally experienced. It was concluded that the poorer performance of the hearing-impaired subjects could in part account for their linguistic and reading difficulties when they are taught in a traditional manner.

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CHAPTER I

INTRODUCTION

Background

In recent years, a great deal of literature concerning the phenomenon of cross-modal transfer has been accumulated.

A simplistic description of this phenomenon is provided by Blank and Bridger (1964) as, ". . . the use of information acquired through one sense modality in solving problems presented in another modality." The factors involved in cross-modal transfer have been examined for various purposes, some of them heuristic. Most of the studies related to this subject have centered around finding instances in which the phenomenon occurs, how it occurs and why some modes of presentation are more amenable to its occurance than others. Among the studies most relevant to education are those conducted by Birch and Belmont (1964) that have related the inability to transfer and integrate information across modalities to reading retardation.

This thesis will present an explanation for the unusually large proportion of reading retardation among the deaf population (Vernon, 1970).

The correlates of reading retardation are of particular concern. The often stated reason for this retardation is language deficiency. But language learning for the school-aged deaf child is based on reading, in which case a more legitimate problem to explore would seem to be the correlates of reading retardation that result in perhaps concommitant linguistic deficiency.

Reading has been characterized by educators as a process involving transfer from visual-spatial symbols to auditory-temporal equivalents. The underlying assumption of this characterization supposes that the language upon which reading is based is auditorally acquired. This assumption is easily appreciated when one is considering teaching reading to a child whose hearing is unimpaired and has, in fact, an auditory language foundation. For such a child, reading is to a large extent a cross-modal transfer performance. For a hearing child, the inability to integrate information across modalities may be the result of inadequate experience with such tasks (Gibson, 1969). However, we are concerned here with an explanation of reading retardation among the deaf.

The language base for the deaf child is visual. This is demonstrated in O'Connor and Hermelin's study of sensory deprivation (1971) which reveals that when a modality of input is restricted, stimuli specific to the non-functional modality are not likely to be coded, especially in the fashion dominant for that modality, e.g. temporal. In other words the deaf child will tend not to process temporal inputs, or may try to convert them since they are specific to only the auditory and tactile modalities. The deaf child learns language visually. If language is visually-based for the deaf and the components of reading are visual-spatial stimuli, then the problem of learning to read is one that is intramodal and not cross-modal and perhaps rather easy. Reading remains a transfer task, but a transfer from concrete objects, spatially distributed to written words, also spatially distributed.

The significance of this paradigm will become clear when we consider the prevailing method of reading instruction for the deaf. When young deaf children are given language training, there is usually a conterminous introduction to reading (McGinnis Method, Tracy Clinic Handbook). Sounds are broken down into phonemes and later combined into sequences. The child is expected to "read the lips" as well as to focus his attention on visible vocal operations (e.g., movements of the jaw), distinguishing facial expressions. Tactile responses are also expected (such as feeling the vibrations of his vocal folds). The child is then expected to integrate and "understand" a sequential arrangement of all these stimuli. Furthermore, the child is then required to use the information he has acquired from this training procedure and reproduce it motorically (involving another modality).

Some investigators (Blank & Bridger, 1964) were unable to elicit cross-modal transfer responses in their younger subjects. Yet many educators and parents expect the deaf child to not only interpret a temporal sequence through a visual modality, but to transfer whatever information is being processed to a motoric modality. Not one, but many visual stimuli are presented. This seemingly impossible task is compounded when the child reaches school age and must begin learning how to "read."

Reading thus becomes another transfer problem. Visual temporally presented stimuli (lip-reading) are associated with visual stimuli that are spatially distributed. All temporal stimuli are expected to be assimilated, processed and transferred to a visual image (a word) and transferred across modalities again to be verbalized. Another dimension to this instructional procedure involves not only processing these stimuli to be stored, but processing them for meaning. Beyond the fact that verbal associations to visual stimuli are expected to be established, the child must be able to identify the word, or visual stimulus, meaningfully; i.e., to recognize its associated concrete object.

Learning to read for the deaf child is a phenomenon so much more complex than it is for his hearing peers that retarded reading and linguistic deficiency would seem to be accomplishments in themselves.

Statement of the Problem

This thesis maintains that linguistic and reading ability for the deaf are one and the same; that competence in both is predicated upon the ability to process perceptual information. The perceptual process with which this study is concerned is the coding of information presented either spatially or temporally within or between different sensory modalities.

Past research suggests that a sensory deficit will impede an individual's performance at the coding and integration of sensory input. This thesis proposes that a sensory deficit such as deafness restricts individuals to the intact sensory modalities for the reception of information to be coded and processed, thus precluding them from experiences available to persons not sensorily deprived. Therefore, facility in cortical processing of sensory information is a function of experience with such information.

Until a plausible explanation of reading retardation among the deaf can be determined, research designed to modify instructional strategies or presentation modality will not be soundly based. The review of the literature (Chapter II) is focused on possible determinants of reading retardation among the pre-lingually deaf population. This examination will be concerned with the perceptual facets of the problem as opposed to the linguistic considerations--although both are significant.

The responses of deaf and hearing children to different modalities and conditions of stimuli for presentation and transfer were evaluated. The optimum presentation and response modalities were determined by a testing procedure involving various modalities and conditions in combination. The findings of the study generated suggestions for alternative methods of instruction and language acquisition for the congenitally deaf child.

CHAPTER II

THEORETICAL AND METHODOLOGICAL BACKGROUND

A Theoretical View: Language and Its Relation to Simultaneous and Successive Processing

While language probably does not function as a mediator in cross-modal operations (to be explicated in the section on mediation), language is a phenomenon which to a great extent is dependent on cross-modal and simultaneous and successive information processing (Hermelin & O'Connor, 1970). As Lashley (1960) so aptly informs us, linguistic performance, including verbal responses and syntactical arrangements of language units, is not a manifestation of structuring which is inherent to the language system. Language performance is, rather, a consequence of a potential characteristic to human beings; i.e., the ability we have to arrange linguistic components into a particular kind of serial order, to perceive such arrangements and otherwise carry out the necessary integration of stimuli across modes for either the delivery or reception of linguistic forms.

Since we owe a significant degree of our understanding of the integrative activities of the cerebral cortex to A. R. Luria, it is appropriate to begin a discussion, concerning the relation of these activities to the phenomenon of language, with this renowned Soviet psychologist. In The Human Brain and Psychological Processes (1966), Luria has provided a division of integrative activity into the two forms introduced by I. M. Sechenov in 1878. These two forms of integration are simultaneous and successive synthesis. Luria related his observation that simultaneous and successive synthesis appear to occur at three different increasing levels of complexity in human behavior, which he designated as the (1) perceptual, (2) mnestic and (3) intellectual levels of operations.

Beginning with an example of an instance of simultaneous processing at the perceptual level, Luria remarked that when glancing at a complicated picture, although one tends to examine the parts gradually, distinguishing the essential elements, ". . . we synthesize them into a single entity, a unified visual structure [p. 74]." Analogously, stimuli felt by the hand are explored consecutively but are integrated into a simultaneous scheme when processed by the brain, and are then rendered as a unified image. Similar processes of synthesis were noted to take place in the acoustic analyzer for example, in the form of chords.

Such synthesis is equally evident at the mnestic level of processing. Lastly, the importance of simultaneous synthesis was stressed as a condition for complex intellectual processes "whether the grammatical system of a language or a system of arithmetical concepts [p. 76]." "The grasping of any system of relationships . . . is impossible without arrangement of the elements into a simultaneously surveyable scheme [p. 76]." This is evident in the fact that a disturbance of the simultaneous function can effect a "disintegration of . . . corresponding grammatical relationships [Luria, p. 76]." On the basis of observations of patients with brain lesions Luria suggested that the parieto-occipital region of the cortex is specialized for the synthesis of elements into spatial groups.

Following his discussion of the levels of simultaneous synthesis, Luria described its perceptual counterpart, successive synthesis. Such synthesis functions in a dissimilar manner to the extent that stimuli are not simultaneously surveyable, but are united into a series such that each stimulus is a part of a serial order in which they are interrelated as links of a chain. Luria has proposed that the parieto-temporal region of the brain is responsible for the synthesis just described.

Examples Luria used to demonstrate this operation at the perceptual level are a melody, in which elements are organized in time, and any skilled movement in which an initial movement evokes the expression of a specific order of other movements, forming a "kinetic melody [p. 78]."

With respect to language, which is a manifestation of a sequential system at the intellectual level, Luria cited narrative speech, confirming Lashley's observations.

In accord with Luria's theory, Lashley delineated language as an advanced form of integrative functioning, when, in an essay entitled, "The Problem of Serial Order," (1960) he described the phenomenon as representing ". . . in a most striking form the integrative functions that are characteristic of the cerebral cortex and that reach their highest development in human thought processes [p. 507]." He pointed out that temporal integration is not exclusive to language, but can be found in all coordinated movements of humans, as well as those of other animals. While temporally integrated actions occur among even insects, "they do not reach any degree of complexity until the appearance of the cerebral cortex [p. 508]."

Considering the structure of the sentence, Lashley suggested that numerous integrative processes can be inferred to take place in the process of their construction. He thus proceeded to describe in detail the hierarchy of integrations involved in the expression of language. Lashley presented a detailed analysis of the pronunciation of a word:

> Pronunciation of the word "right" consists first of the retraction and elevation of the tongue, expiration of air and activation of the vocal chords; second,

> depression of the tongue and jaw; third, elevation of the tongue to touch the dental ridge, stopping of vocalization, and forceful expiration of air with depression of the tongue and jaw . . . . Pronunciation of the word "tire" involves the same motor elements in reverse order. Such movements occur in all permutations [p. 509].

Not only has Lashley presented a very graphic account of the complexity of the enunciation of a word, even more importantly, he alerts his readers to the fact that the order of the motor elements is not due to an intrinsic association between them, but is instead the result of the control or direction of some discrete agent. Lashley next advanced his proposal to account for the syntax of sentences.

> From such considerations it seems to follow that syntax is not inherent in the words employed in the idea to be expressed. It is a generalized pattern imposed upon specific acts as they occur [p. 511].

Lashley presented a convincing argument to demonstrate the generality of the problem of syntax in the following statement:

> . . . the problems raised by the organization of language seem to be characteristic of almost all other cerebral activity. There are a series of hierarchies of organization: the order of vocal movements in pronouncing the words, the order of words in the sentence, the order of sentences in the paragraph, the rational order of paragraphs in a discourse [p. 515]. (emphasis added)

By providing a comprehensive analysis of the symbolic modes including visual imagery and language, Paivio, in his book entitled Imagery and Verbal Processes (1971), developed the theoretical discussion concerned with the integration of stimuli. Paivio imparted a modality-specific viewpoint when he expressed that the verbal system is specialized for sequential processing dealing with temporally organized patterns, while visual perception can be regarded to be specialized for parallel processing of spatial stimuli. He spoke of Neisser, who suggested a principal of operationally parallel functioning in addition to parallel organization of stimuli. Operationally parallel functioning is not necessarily simultaneous, as parallel functioning is. Instead, if items can be serially ordered but any element in a system is not dependent on the outcome of another, they function independently. On the other hand, sequential processing is defined by the interdependency of the units in the sequence, i.e., one point in a sequence is determined by the point prior to it and in turn determines the next in the series. Visual imagery, according to Paivio, is a parallel processing system, both spatially and operationally, but it has a capacity for serial processing.

Paivio found parallel and sequential processing features in the verbal symbolic system as well. However, he qualified, because the verbal symbolic system is functionally associated with the auditory-motor system it is only operationally parallel. He claimed that due to "considerable freedom of choice or independence of the units at any level--one is free to say what one wants and there are different ways of saying it; this process is operationally parallel [p. 36]." However, this argument seems a bit weak. Paivio's statement that meaning is determined by the orderly arrangement of units is more convincing.

There has been some research which has called into question the existence of the simultaneous and successive processes. These conditions may or may not occur in the processing of information as described by the above investigators, but it appears important to retain these constructs for the purpose of describing the nature of input and response (see Tulving & Lindsay, 1967; and references they make to Treisman & Broadbent and Gregory).

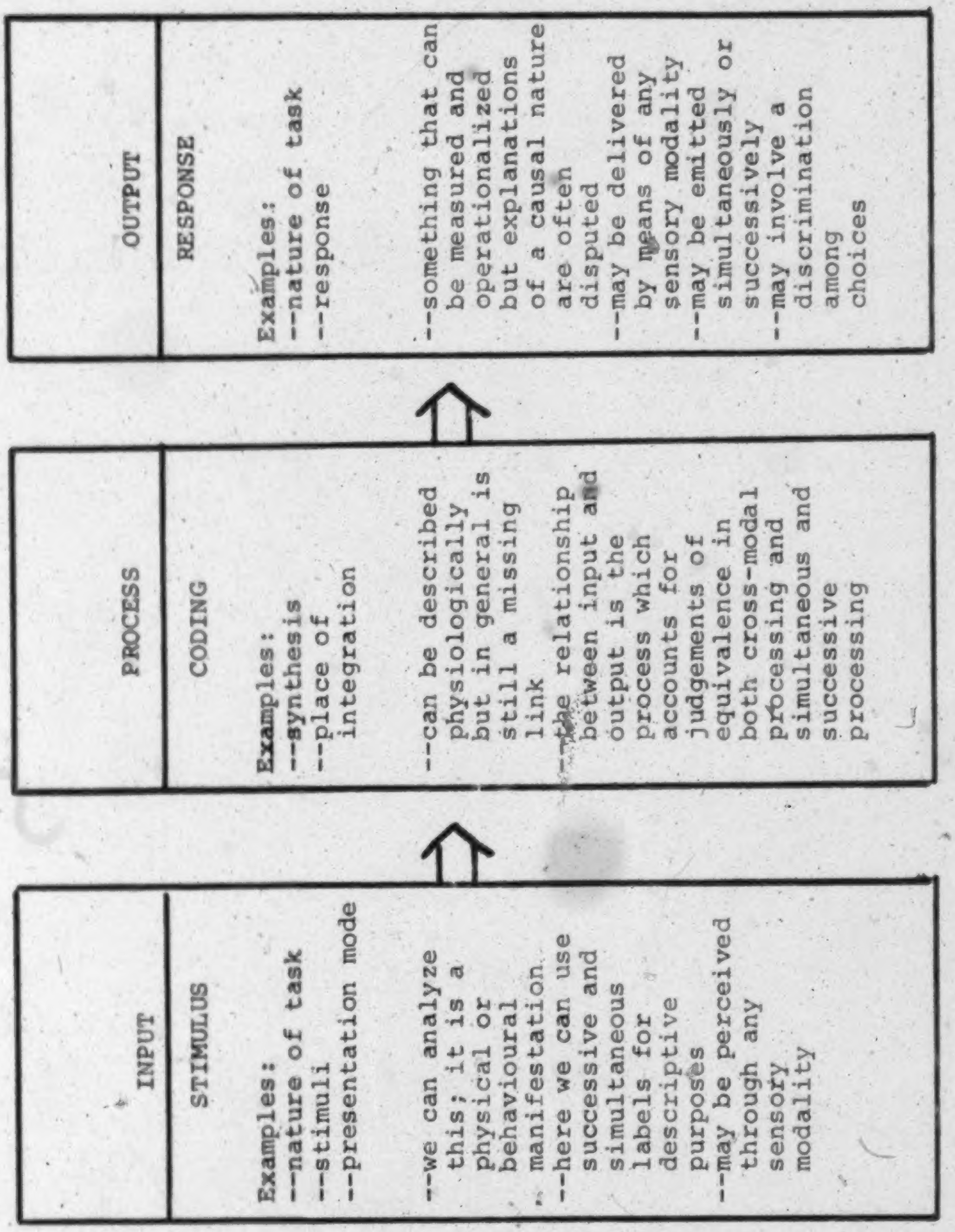
Physiological Attempts to Explain Integrative Processes

Most of the research is in agreement regarding the obvious--that there is an integrative mechanism responsible for the synthesis and equivalence of different sensory modes. That experiences seem to be (1) equipotential and (2) intermodaly reciprocal, has led many investigators of this phenomenon to conceive of cross-modality as a function regulated by a discrete mechanism which operates independent of the efferent system. The questions, however, remain: What is it? Where is it? What color is it? How many is it? The pursuit for some physiological manifestations of this mechanism to provide observable evidence of its existence is not wholly dissimilar to the evolutionists' search for the hypothetically deduced missing link.

It is perhaps the case that process can be hypothesized on the basis of an understanding of input and response--the conceptualization to follow is an illustration intended to explicate a relationship: that of the input, process, response trilogy (see Figure 1).

This framework should elucidate some of the structural ambiguities concerning the *system* of cross-modal coding and simultaneous and successive processes. Though the "process" could be the same mechanism ~~respon~~sible for both cross-modal integration and the integrative activity of simultaneous and successive integration, they may on the other hand be different mechanisms. It would be the case that the mechanism is the same for both processes if stimuli were in fact modality-congruent. The illustration, however, is intended to apply to both.

This is not an attempt to suggest that by such an effort we can derive an explanation of the "process" which will be empirically satisfactory. However, the conjecture does suggest a viable direction of concentration for further research, as well as a framework from which to examine the research in retrospect. This is to say that information describing the contingencies relating input to response would enhance our efforts to understand the conduct of the *process*. Possibly, once we are capable of



INPUT

STIMULUS

Examples:
- --nature of task
- --stimuli
- --presentation mode

- --we can analyze this; it is a physical or behavioural manifestation
- --here we can use successive and simultaneous labels for descriptive purposes
- --may be perceived through any sensory modality

PROCESS

CODING

Examples:
- --synthesis
- --place of integration

- --can be described physiologically but in general is still a missing link
- --the relationship between input and output is the process which accounts for judgements of equivalence in both cross-modal processing and simultaneous and successive processing

OUTPUT

RESPONSE

Examples:
- --nature of task
- --response

- --something that can be measured and operationalized but explanations of a causal nature are often disputed
- --may be delivered by means of any sensory modality
- --may be emitted simultaneously or successively
- --may involve a discrimination among choices

Fig. 1.--Conceptualization of the relationship between stimulus, coding and response.

determining a physical representation of the features of cerebral organization, we can use our knowledge about the nature of a stimulus and response to account for the equivalence among sensory modes and the way in which transfer occurs, including the nature of simultaneous and successive integration.

What follows is a summary of just such a search for an integrative mechanism. Three persons in particular have presented cogent descriptions of the physiological activities hypothesized to be responsible for simultaneous and successive processing and modality equivalence.

Attempts to explain the mechanisms involved in cerebral integrative functioning seem to have begun with Luria (1966) and his studies of brain-damaged patients. Observing that disturbances in the visual and acoustic spheres resulted from lesions in specific areas of the brain led Luria to conclude that certain areas of the cortex specialize in the synthesis of stimuli into simultaneous groups and successive series (p. 79):

> Whereas lesions situated within the parieto-occipital region of the cortex causes disturbances of the synthesis of elements into simultaneous (spatial) groups, investigations of patients with lesion of the anterior regions of the brain and primarily of the frontal-temporal regions, yield completely different results . . . . They are primarily associated with the analysis of stimuli separated from each other in time and with their synthesis into successive series [p. 103]. (emphasis added)

Luria's claim that integrative functions tend to be modality congruent or (he might prefer) modality specialized, is a deduction derived on the basis of observing impaired subjects, which for some seems to be an unsophisticated jump to conclusions. However, the association between particular sensory modes and certain integrative functions is not entirely unfounded, as other research has demonstrated.

K. S. Lashley (1960) submitted that there appears to be a mechanism responsible for parallel and sequential organization. Lashley concluded that nervous organization probably consists of "elaborate systems of interrelated neurons capable of imposing certain types of integration upon a large number of widely spaced effector elements [p. 520]." He hypothesized that successive and simultaneous systems are distinct in that successivity seems to be a manifestation of temporally distributed waves of effector excitations, while simultaneity occurs when receptor and effector elements are directionally polarized. Lashley referred to these processes as "a sort of substratum upon which other activity is built [p. 520]."

With regard to language, a recognized complex type of integration, Lashley posited that before words are used in a sentence they may be held in a state of partial excitation, or "primed," as he designated it, while another neural system scans the arrangement to determine the order in which the sentence will be emitted: "that elements of the sentence are readied or partially activated before the order is imposed upon them in expression, suggests that some scanning mechanism must be at play in regulating their temporal sequence [p. 422]." Lashley's position rests in the hypothesis stage of sciencing, but represents a very credible viewpoint nonetheless.

Karl Pribram, in Languages of the Brain (1971), seemed to concur with Lashley. He discussed the work of Don Perkel and Theodore Bullock (1971, p. 74), who have studied simultaneous and successive coding in fish. Although Pribram had not been able to isolate analogous processes in the human brain, he suggested that it is highly possible that such coding operates in man as well. Essentially, Perkel and Bullock examined the radar-like signals discharged by the electric organs of the fish. There appeared to be evidence of temporal codes in the form of

> . . . shifts in latency, the duration of bursts, the overall probability of firing and the variation in this probability, the incrementing or decrementing of firing or its rate of change are all altered in one or another set of conditions [p. 74].

Perkel and Bullock referred to the spatial coding that they observed as "ensemble" processing. Arrays of parallel nerve fibers or spatially distributed "impulse trains" were observed to suggest this. As Pribram reported, Perkel and Bullock hypothesized that probably another mechanism in the Central Nervous System was responsible for integrating the messages. Pribram logically inferred that such a mechanism would account for the integration of stimuli in the human brain. He believed this mechanism to "take place at neural junctions in the production of slow potential microstructures resulting from the interactions among ensembles of neighboring and successive impulse coded signals [p. 74]." It is evident that before psychologists will accept this account, Pribram's physiological explanatory "package" must be adopted in its entirity. Only further research can determine its validity.

Summary

Three noteworthy investigators, Luria, Lashley and Paivio, have commented on the phenomenon of language and its relation to certain perceptual processes. All three maintained that the conduct of language at various levels of complexity is dependent upon cortical information processing of a binary nature. These processes are simultaneous and successive integration of stimuli perceived through visual, auditory and tactual modalities.

Luria discussed the (1) temporal aspects of successive synthesis in which a serial order dominates the organization of discrete stimuli, and (2) an apparent spatial dimension of the integrating mechanism which permits stimuli to be surveyed concurrently. This dimension is proposed to account for the human ability to understand and generate grammatical units in the form of relationships.

Lashley elaborated on Luria's conceptual framework by describing the multi-organizational operations essential for the production of language. The integration of these operations is attributed to some supra-ordinate controlling mechanism.

Paivio tendered the notion that particular sensory modalities appear to be specialized in dealing with the two integrative functions just described. This notion bears a marked resemblance to Luria's suggestion that specific areas of the brain are specialized for simultaneous and successive processing.

The three investigators under discussion have contributed a great deal to our understanding of the nature of perceptual stimuli and their relationship in behavioral and linguistic contexts. But the first two, Luria and Lashley, and another, Pribram, have made attempts to determine the physiological process by which stimuli are cerebrally integrated.

Luria proposed that there appears to be some evidence for areas of the brain which are specialized for dealing with simultaneous or successive series of stimuli. These areas, not by chance, correspond to the loci of visual and auditory perception. Luria thus posited the locations in the brain where he believed integrative functions take place.

Lashley offered a description of integration which is even more specific than that of Luria. He arrived at an explanation which suggests that there is a scanning mechanism made up of ". . . elaborate systems of interrelated neurons [1960, p. 520]," which would account for the ability to integrate stimuli. Pribram, on the other hand, submitted that human spatial and temporal processing operates much like that which Perkel and Bullock observed in fish, and regards processing to be the result of ". . . interactions among ensembles of . . . impulse coded signals [1971, p. 74]."

Each of these attempts to explain the physiological nature of the integrative mechanisms, or processes, are logically sound, but the actual process as yet remains empirically unidentified. It is reasonable to conclude then, that these attempts are, in fact, only hypothetical constructs. This thesis will therefore attempt to discuss the problem of integration in terms of what can be measured and identified, i.e., to discuss the conduct of input and response.

Comprehension Notwithstanding: The Reading Process

When we speak of reading in education today we are often inclined to elevate it to an almost mystical level of complexity. An attitude of this kind generally regards reading as a phenomenon inseparable from its associated linguistic components. However, reading can be analyzed as an independent phenomenon when we consider it in terms of process and not function. Reading is very simply a decoding process. It is a process that requires transfer of written material from a visual to an auditory mode. When a child learns to read, he perceives words (visual input) and then says them aloud or to himself (decodes them into an auditory mode). Clearly, this process assumes that the mode into which the word is coded (the oral mode) is intact. Reading is thus considered to be auditorally based and the predominant method of teaching reading is an oral one. We refer to this process of transferring visually-perceived words to verbalizing them as The Look-Say Method or cross-modal transfer (transfer from a visual to an auditory mode or an auditory to a visual mode).

Stimuli distributed in a temporal fashion are judged to be more specific to processing by the auditory modality due to the nature of auditory perception, whereas stimuli distributed in a spatial fashion are more likely to be processed by the visual modality.

There is reason to believe that the deaf will be poorer than their hearing peers at solving cross-modal tasks involving transfer from a temporal to a spatial mode of processing and a spatial to a temporal mode. Hermelin and O'Connor (1971) have dealt with sensory deprivation studies demonstrating that (1) hearing subjects show a preference for coding information temporally, and (2) deaf subjects have a tendency to process information spatially.

It is hoped that an examination of the literature and the study following it will suggest an optimum method of instruction for the deaf, whereby information will be processed efficiently and reading difficulties will be minimized.

The following representation shows that there can be an interaction across modes and between conditions. Each mode can be presented in either a simultaneous or successive condition. That is, a pattern of stimuli can be presented all at once in a spatial array or in discrete units temporally distributed. A schematic representation of the cross-modal transfer process appears in Figure 2.

A Correlate of Reading Achievement:
Cross-Modal Ability

Although the manner in which information is processed by the brain is important for our understanding of the perceptual aspects of deafness, our investigation is not complete until the nature of the reading process is more thoroughly understood.

In their 1964 studies, Birch and Belmont attempted to relate cross-modal transfer (CMT) success to the ability of learning to read. Referring to a study by Harris (1964, p. 858), Birch and Belmont pointed out that reading involves learning to recognize visual counterparts of auditory symbols. This basis begins the framework of their hypothesis: "A primary disturbance in the ability to integrate stimuli from the two critical sense modalities, hearing and vision, may well serve to increase the risk of

Independent Variables

Modes: auditory
visual
tactile

Conditions: simultaneous
successive

Dependent Variable

task results

X = Cross-modal transfer

O = No cross-modal transfer

		PRESENTATION MODE		
		AUDITORY	VISUAL	TACTUAL
RESPONSE MODE	AUDITORY	O	X	X
	VISUAL	X	O	X
	TACTUAL	X	X	O

Fig. 2.--A schematic representation of the cross-modal transfer process.

becoming a poor reader [1964, p. 858]." In an experimental setting, subjects were required to identify a visual-spatial dot pattern following presentation of a corresponding auditory-temporal sequence and vice versa. This task implicitly involved a recognition of the equivalence of these modalities and a transfer of learning. Results of 150 retarded and 50 normal readers were then compared to reading achievement, As predicted, poor readers were less able to integrate stimuli across modalities than good readers, although reading incompetence is not entirely attributed to cross-modal transfer. Evidence cited to support the proposition is the same as that used to substantiate mediational theories, i.e., CMT is not an ability characteristic of young children and animals (Gibson, 1969, p. 220). Although CMT has been observed to occur later in development, for the most part (such as the failure of 3-year olds to perform CMT tasks, but success for 5-year olds) the assumption that development alone is responsible is not convincing.

It may be that the ability to perform such tasks does not become manifest until experience in the performance of these activities has been established. O'Connor and Hermelin (1964) suggested that experience with modality-specific processing and coding is effective in eliciting transfer abilities. "Tactile presentation may have to be more frequent for the formation of a stable image which could be transferred to another modality [p. 234]." Further evidence is indicated by the observation that transfer from successive auditory stimuli was found to be less difficult for young hearing subjects (Furth, 1966, p. 447). Furth stated that linguistic experience provides practice in "discriminating and learning combinations of sequentially presented material [p. 447]." He advanced that an experiential deficit in sequential tasks is cause for the inferior scores of the hearing-impaired subjects on successive tasks.

An experiment reported by Carterette and Jones (1967) supports Furth's conclusion. Carterette and Jones described their experiment as part of a series which examined the influence of linguistic redundancy on the ability to learn verbal material. This experiment, in particular, sought to investigate the precision with which subjects respond to auditorally and visually presented verbal material. Three groups of children at different age levels were compared with adults on tasks requiring continuous processing of sequentially presented information. This procedure was chosen on the basis of its resemblance to the reading and listening process. Subjects were merely required to respond by saying "old" or "new" to the presentations. Experimenters concluded that modality of presentation was a significant factor in language processing leading them to suggest that visual and auditory presentations are not equally as effective for the presentation of verbal information at all ages. Despite the fact that words of high language frequency were presented, younger children performed more poorly than older ones and adults for visually presented lists. Accuracy for visually presented material increased with age until adulthood when processing of visual material was equal to that of auditory. The experimenters inferred that differences were probably due to experience. The school, in which students are required to attend to visually presented information, provides such experience.

Summary

It has been suggested that the ability to integrate stimuli from the visual to auditory or auditory to visual modalities is necessary for becoming an adequate reader (Birch & Belmont, 1964). Several investigators (Carterette & Jones, 1967; Furth, 1966; O'Connor & Hermelin, 1964) have concluded, on the basis of empirical findings, that experience with cross-modal coding is responsible for the differences found between those who perform well and those who perform more poorly on tasks involving judgements of equivalence between modes, i.e., reading tasks.

After Information is Stored: The Process of Cross-Modal Transfer

The general procedure for cross-modal transfer experiments involves (1) training a subject in one modality to make responses to a set of stimuli and (2) following training, to make similar responses to stimuli that are equivalent or resemble that of the training task, but (3) are presented in a different modality. Transfer is considered to have taken place if the subject was able to identify corresponding stimuli in another modality. It is assumed that recognition of a stimulus presented in another modality is facilitated by the training procedure. Cross-modal research has included transfer from tactile, visual and auditory modalities involving all permutations of these in combination. Whether or not verbal mediation is necessary for translating one type of modality input into another has been debated.

Cross-Modal Transfer: The Mediation Hypothesis Versus The Developmental and Learning Viewpoint

A. The mediation hypothesis. The mediation hypothesis implies that CMT is a characteristic of the verbally-inclined: those who are familiar enough with the manipulation of language symbols to describe the invariant features of modality inputs and transfer them to equivalent stimuli in another modality.

In an experiment in which transfer effects from touch to vision and vision to touch were measured, Gaydos (1969) concluded that "verbalization seemed to play an important part in the learning for many of the subjects [p. 109]." The experimenter postulated that verbal associations established in training could facilitate subjects' performance on subsequent discrimination tasks. During the initial sessions, subjects in the experiment were trained to pair the names of males with specific shapes. Those subjects who discriminated shapes across modes at the fastest rate (i.e., the fastest learners) did, in fact, resort to the verbal associations they acquired during training (p. 109).

Other mediational theories are founded on the evidence that younger children (pre-verbal) and animals (non-verbal) often fail problems requiring cross-modal transfer. Such studies have been cited by Gibson (1969) and Hermelin and O'Connor (1964, p. 229). The most often noted studies performed with monkeys have been those of the early 1960's. Ettlinger (1960) and Wilson (1963) reported weak and negative results in experiments which required monkeys to transfer cross-modally from a visual discrimination to a tactual one or tactual to a visual discrimination task. Hermelin and O'Connor (1964) inform us of some findings that would seem compatible:

> Wilson and Wilson found that monkeys with lesions in the parietopreoccipital area showed no facilitation

> in visual learning tasks from prior tactual experience. On the other hand, O'Connor and Hermelin demonstrated that some cross-modal recognition between visual and verbal material . . . occured in severely subnormal subjects [1964, p. 229].

Blank and Bridger, in another experiment (1964), aimed towards discovering the importance of verbal mediation, and postulated that there are in fact two kinds of cross-modal transfer (CMT). In one experiment the children held objects that were not equivalent, but characterized properties similar to those objects they perceived visually: stimuli were dissimilar but analogous. This problem Blank and Bridger termed cross-modal concept (CMC). In the other experiment they observed the children's ability to discriminate which of two objects they perceived visually, was identical, or "equivalent" to an object they perceived haptically (cross-modal equivalence or CME). The former was assumed to require mediation because transfer was to an analogous but not equivalent stimulus. On the other hand, cross-modal equivalent problems were considered to involve corresponding stimuli in another modality. Blank and Bridger hypothesized that CMC would be language dependent and CME would not. Although the results supported their predictions, it was found that verbalization alone is insufficient for CMC transfer: "Several children labelled the stimuli one and two and still failed to solve the problems [1964, p. 287]." Language was, therefore, a necessary but not sufficient function of solving CMC problems.

To counter these findings, Gibson also pointed out that other studies have obtained dissimilar results. Studies conducted by O'Connor and Hermelin (1964, 1965, 1971) and Furth (1964, 1966, 1967) on the deaf have supported this attitude. In tests to discover the dependence of cross-modal transfer on words, O'Connor and Hermelin found no difference in groups with different verbal ability. "Thus words probably play no decisive part in this type of transfer between sensory systems [1964, p. 233]."

Having determined that language plays only a minor part in cross-sensory transfer tasks, we are led to consider another viewpoint to account for the phenomenon.

B. The developmental and learning viewpoint. This viewpoint proposes that the ability to integrate stimuli across modalities is a function of learning (Gibson, 1969). Emphasis is given to the unity of the senses. This approach states that sensory modalities begin as distinct and specific abilities from birth. At this time CMT would not be possible, but during development these functions are integrated. To the extent that learning takes place in the presence of development we may consider CMT as a "perceptual development" that takes place through learning. Discovering transformational features could be viewed as a result of learning experiences.

Gibson has discussed Piaget's developmental viewpoint:

> . . . progressive development of exploratory handling with increasing search for significant features. The sensory-motor schema is a kind of referrent common to two modalities, making cross-modal transfer possible [Gibson, 1969, p. 230].

Gibson has remarked, appropriately, that this concept is a difficult one to test.

Two experimenters, Gibson also noted, support a developmental viewpoint. Birch and Lefford (1963) presented as evidence developmental curves for intermodal matching which indicated that correct matching increases with age. Her own analysis of the process introduced the notion of amodal invariants in stimulation. These amodal invariants Gibson defined as higher order properties of stimulus information which are not sensation specific. Intensity, extent and temporal and spatial patterns are examples (1969, pp. 220-221). These examples are not unlike those conditions, simultaneous and successive, that are considered to be modality-congruent by other investigators (Hirsh, Bilger & Deathridge, 1956; Birch & Belmont, 1964; O'Connor & Hermelin, 1971). Gibson did not deny that features of stimuli can be modality-congruent, but she preferred to concentrate on modality features that are common to several different modalities. She termed this relational. Gibson's examples seem to indicate that she has redefined modality-congruency.

In the O'Connor and Hermelin study (1971), subjects deprived of experience in specific sensory modalities were unable to perform tasks that demanded their attention to stimuli in the non-functioning modality. Although visual-temporal choices were available, deaf subjects tended to ignore them because of their restriction to the visual modality and hence visual spatial coding. The deaf and blind subjects in this experiment constituted good control groups to demonstrate the learning and experiential facet of cross-modal transfer.

Process as a Function of Presentation: Are Stimuli Modality-Congruent?

While there seems to be no hard and fast associations between the nature of stimulus presentation and sensory modality, most of the research lends support to the view that spatially distributed stimuli are best apprehended through vision while temporally distributed stimuli are more easily perceived through audition. For those persons whose sensory receptors are intact, stimuli are perceived in either a spatial or temporal fashion.

One of the earliest studies to suggest a relationship between patterns generated over time and their dependence on auditory perception was performed by Hirsh, Bilger and Deathridge (1956). The duration of tone and light stimuli was considered within auditory and visual contexts respectively.

Subjects were presented with two stimuli: an auditory stimulus (a tone) and a visual stimulus (a light) against a background of auditory noise (90 db) in the first condition and against a background of quiet as the second condition. Afterwards, subjects were asked to report the durations of the stimuli. Responses of the subjects indicated that when the duration of a tone or light was held constant during each condition, subjects' perception of their duration differed markedly relative to the level of background auditory stimulation. Hirsh, Bilger and Deathridge concluded that "perceived time varies with the level of auditory stimulation [p. 562]." In a second part of the experiment, auditory and visual stimuli were presented against a background of visual ambient stimuli (brightness) and darkness. When the subjects were required to reproduce the duration of these stimuli, there appeared to be no difference in perception of durations when tone or light had been presented against a background of varying levels of brightness.

The experimenters summarized these results conclusively in the following statement.

> . . . in this study only acoustic and not visual, ambient stimulation seems capable of eliciting marked changes in the rate at which the psychological clock operates [p. 572].

The results indicate that perceived duration of a tone or light is significantly dependent on the level of auditory stimulation, but these stimuli are little affected by visual ambient stimulation.

Later, the notion that the extent of cross-modal transfer is subject to variations of conditions (simultaneous and successive presentations) was advanced by Krauthamer (1959). In this experiment, subjects were presented with a series of patterns under two conditions. In the first, patterns were traced with a stylus of pin-pointed light (successively) and in the second, drawings of metal dies were presented (simultaneously). Transfer occurred across vision and touch modalities. Although Krauthamer's study did not describe the precise nature of the dependence of modality transfer on conditions of presentation, the results of the study lean in the direction of a modality-congruent viewpoint, such that "the extent of transfer depended on conditions of the stimulus [1959, p. 396]."

Developing this concept even further, Birch and Belmont (1964) explored the relationship between a temporally structured set of auditory stimuli and a spatially distributed set of visual ones. Apart from the fact that they were trying to determine the correlation between reading retardation and success at cross-modal coding tasks, Birch and Belmont built into their experiment a modality-congruent feature, i.e., a visual dot pattern was spatially distributed and corresponded to a rhythmic auditory pattern, temporally distributed. The assumption implicit in this presentation was that auditory-temporal stimuli can be made equivalent to visual-spatial stimuli. Because reasons for pairing of these modes and conditions were not provided by the experimenters, we can only assume that Birch and Belmont recognized their modality-congruent attributes.

The hypothesis Birch and Belmont (1964) set out to test was supported by their findings. These findings indicated that retarded readers differ significantly from normal readers on the experimental tasks. The results suggested therefore, that retarded readers of normal intelligence are less proficient judges of auditory-visual equivalence.

In another auditory-visual sequencing experiment, there was no pairing into auditory-temporal and visual-spatial arrangements as in the Birch study. Furth (1966) conducted an experiment in which visual material was presented both simultaneously (spatially) and successively (temporally) and auditory stimuli were successively (temporally) presented. Deaf and hearing subjects were compared in their performance on these tasks. Deaf subjects demonstrated greater success with simultaneous than with successive sequences. The hearing subjects did better than the deaf on successively presented material, regardless of the modality. Furth attributed the difference between groups to experiential factors. The results of this later experiment (Furth, 1966) differed from an earlier one in which fewer differences were found between successive and simultaneous sequence learning; "mean sequence errors between the aphasic and deaf group yielded to well below acceptable criteria of significance [Furth, 1964a, p. 176]." These negligible differences indicated to Furth that any difficulties were due to the combinative aspect of sequences. He suggested that, ". . . there may not be too much difference between these modes of presentation [p. 352]." Furth's interpretation is contrary to a more recent experiment of O'Connor and Hermelin (1971) which will be discussed in the latter part of this section.

Work being done in the Soviet Union by Luria (1966) appears to differ with Furth's interpretation of the relationship between auditory and visual sequences. Luria has developed the concept of visual, motor, tactile and acoustic analyzers that organize stimuli into simultaneous and successive groupings:

> It is well known that the tactile and also to a large extent the visual analyzer receives a successive series of stimuli but integrates this series into simultaneous groups. . . . However, the main form of operation of these (motoric and acoustic) analyzers is the *conversion of this original scheme* into an expanded serially organized successive group [1966, p. 125-126]. (emphasis added)

While approaching a semblance of the O'Connor and Hermelin paradigm (to be discussed later) of modality-congruent attributes, Luria's explanation of the processes involved in perception diverges nonetheless. He proposed that stimuli presented successively through the visual channel will be reorganized into simultaneous groups in processing and coding and that the converse will be true for the auditory mode. This suggests that the nature of the stimulus input will be altered into the modality-congruent condition when it is received by an analyzer. O'Connor and Hermelin later demonstrate that stimuli presented in a successive or temporal condition will be ignored if the modality of input is visual.

Roman Jakobson (1967) whose interest in the sequential character of speech has led him to investigate the relation between visual and auditory signs, concurred with Krauthamer (1959) and Birch and Belmont's (1964) viewpoint concerning modal attributes. Jakobson has told us that, "In visual signs it is the spatial dimension which takes priority, whereas the temporal dimension takes priority in auditory signs. Auditory signs act in a time sequence [p. 3]."

An experiment giving support to Jakobson's notion that the temporal dimension assumes priority in auditory signs was performed by Harris Savin (1967). Subjects were presented with simultaneous auditory stimuli (a different message to each ear occurring at the same time). Rather than combining the perceptions of each ear, subjects reported messages heard by each ear successively. These results demonstrated that subjects could not group simultaneously presented messages simultaneously when the input was auditory. Similarly, Luria submitted that simultaneous information will be converted to a successive condition by means of an "analyzer." Savin suggested that auditory stimuli can only be perceived successively.

Tulving and Lindsay brought into question the sequential processing hypothesis that has been invoked to explain the ability of subjects to respond to simultaneously presented auditory stimuli. They attempted to demonstrate the non-existence of a "temporary pre-perceptual store" in which information from one channel is said to be held in store prior to processing. This pre-perceptual store, as postulated by Broadbent allows attention to be directed to another channel.

By estimating the shortest period of time in which information can be processed but controlling the duration to obviate attention switching, Tulving and Lindsay attempted to demonstrate that stimuli would be identified as accurately as would be the case for a longer duration of input.

If, as expected, inputs from two different modalities could be processed as accurately when presented for a short duration as when presented for a longer one, the results would support the notion that stimuli were not successively attended to, but that some other process was responsible for the ability of subjects to identify both stimuli. They suggested that duration would be the critical variable in a test of the sequential hypothesis.

Stimuli were of two varieties: (1) visual stimuli consisted of circular patches of white light and (2) auditory stimuli were pure tones. Stimuli were varied along the dimensions of intensity and duration. Four different tasks were presented; two of which presented two stimuli simultaneously from both modalities, and subjects were required to make judgements and attend to both. The amount of transmitted information per modality was the main response variable.

Results failed to find a significant interaction between duration and intensity, indicating relatively no difference between response accuracy in the short and long duration conditions. The tenability of the sequential processing hypothesis was doubtful.

Tulving and Lindsay concluded that explanations for the data appeared to be more compatible with some views of the attention mechanism than with the sequential hypothesis. These findings should be considered with respect to the experiment by Savin, just described, in that the conclusions of Tulving and Lindsay imply that simultaneous processing of auditory input may indeed be possible given the appropriate circumstances.

Bennet Murdock (1969) set out to demonstrate that studies indicating the superiority of short term memory when stimuli are presented in an auditory mode were not entirely valid as evidenced by the fact that the auditory mode is simply more compatible with temporal distributions (p. 378). Murdock experimentally attempted to provide both a spatial and a temporal distribution which could be used in either an auditory or visual presentation. To accomplish this he constructed an apparatus in which eight loudspeakers were arranged in a clockwise display and had eight slide projectors focused on them. "Each item thus had a unique temporal and spatial position [p. 379]." Words were sequentially projected on the eight speakers and subjects were required to find the spatial position of temporally presented stimuli. The results of Murdock's experiment did not support his hypothesis; i.e., he determined that temporal associations are not required in STM experiments. Correct responses could be determined by spatial position although he found fewer errors for the auditory than the visual presentation. Murdock's attempts to effect a separation between auditory-temporal and visual-spatial distributions precede an even more impressive design carried out by O'Connor and Hermelin (1971) attempting to demonstrate modality associations.

Along these lines, O'Connor and Hermelin (1971) have summarized a good deal of research concerned with the view that visual and auditory input are related to temporal and spatial perception. Their own experiments have explored this concept further and demonstrated that among persons whose sensory experiences are limited to one distal receptor, stimuli will be organized according to the remaining modality of input. Their results indicated that in ambiguous situations, stimuli will be organized spatially or temporally depending on the nature of the input (auditory or visual); i.e., hearing and seeing children would respond in a like manner to their deaf and blind peers. One group of blind, one group of deaf and four groups of normal children, two of which were artificially restricted visually or auditorally, took part in the experiment. Subjects seeing (or hearing) a visual (or auditory) display of digits presented spatially and temporally, were instructed to choose the "middle" one. Spatial choices always coincided with temporal choices, so that the subject was forced to choose between them. Results consistently showed that in those cases where information was presented visually, subjects always chose the spatial unit and accordingly, when the stimulus was auditory, subjects made a temporal choice. For example, if the digits 8, 5 and 3 were successively displayed, 5 might be exposed first, then 3 and then 8. The temporal middle would be 3; the spatial middle would be 5. Deaf subjects would have chosen the spatial middle, 5.

The investigations conducted by O'Connor and Hermelin and their predecessors offer provocative evidence concerning the modality-congruent operations of the deaf. If the deaf are restricted to one modality of input, specifically the visual, and therefore primarily process only spatially presented information, then suggestions can be made that perhaps (a) current attempts in the field of deaf education to teach the congenitally deaf to process auditory temporal stimuli when they are unable to perceive such a sequential arrangement are doomed to be unsuccessful; and (b) those who are successful in their speech training sessions have somehow managed to rely on attendant spatial cues to process for meaning.

The instructional implications are obvious. If temporal stimuli are being presented to the deaf, but only spatial coding is being processed, then instructional modification should involve an emphasis on the visual-spatial distribution of materials.

General Summary

The results of a study testing the mediation hypothesis (Gibson, 1969) suggest that language appears to be a necessary but not sufficient mediator in cross-modal transfer tasks. O'Connor and Hermelin (1964, 1965, 1971) and Furth (1964, 1966, 1967) determined that language was not at all necessary for the performance of cross-modal transfer. A few investigators (O'Connor & Hermelin, 1964, 1965, 1971; Furth, 1964, 1966, 1967) have ascertained that the ability to integrate stimuli across modalities seems to be a function of learning and experience.

Most of the studies to date (O'Connor & Hermelin, 1971; Murdock, 1960; Savin, 1967; Jakobson, 1967; Krauthemer, 1959; Hirsh et al., 1956; Birch & Belmont, 1964) have concluded: (a) that stimuli tend to be modality-congruent, that is, simultaneous spatially distributed stimuli are best perceived through the visual modality, and successive spatially distributed stimuli are more easily apprehended through the auditory modality; and (b) that auditory-temporal stimuli could be made equivalent to visual-spatial stimuli.

Studies such as Furth's (1966), conducted with deaf subjects, presented visual-simultaneous, visual-successive, and auditory-successive stimuli and found that deaf subjects performed better on visual-simultaneous than on visual-successive and auditory-successive stimuli. These results were perhaps due to the modality-congruent attributes of the stimuli as well as the experiential factors. Luria (1966) proposed that all visual stimuli would be organized into simultaneous groups during processing, regardless of the condition of input (simultaneous or successive); the opposite would be true for the auditory modality.

These studies all seem to imply that modality-congruent attributes of stimuli are indeed important.

The implication would suggest that differences between deaf and hearing groups would be especially evident in responses which required transfer involving stimuli that are or are not modality-specific. From the earlier discussion of experience, it seems that persons lacking in experience with a particular modality would do more poorly on tasks requiring cross-modal transfer than those who have acquired experience. Noting these two possibilities, we might generate a third: due to modality-congruent attributes, persons who lack experience with a modality will also lack experience with a condition. Thus, deaf children lacking experience with the auditory modality will necessarily be deficient in making decisions of equivalence with regard to transfer to or from successive stimuli.

CHAPTER III

DEFINITIONS AND HYPOTHESES

Definitions

General Terms

Stimulus. In *A Glossary of Behavioral Terminology*, White (1971) defines "stimulus" as follows.

> All objects . . . and events . . . in our environment are considered to be stimuli due to the fact that we are aware of them only inasmuch as they "stimulate" our senses (i.e. we must hear, see, touch or smell them before we know them to exist). Generally speaking we refer to an object or event as a stimulus if it occurs prior to or simultaneously with the response [p. 165].

Thus the operational definition of "stimulus" in this thesis is "inputs from different sensory channels."

Transfer. White (1971) defines this term with the following statement. "Where the cues or relevant stimulus dimensions . . . for problem solution in one instance remain constant in another instance [p. 184]."

Cross-modal transfer. ". . . involves the transfer of a principle . . . . Essentially a discrimination based on a dimension or cue in one sensory modality is transferred to a different sensory modality using the same dimension or cue but in relation to a different discriminada [O'Connor & Hermelin, undated, p. 2]."

Intra-modal transfer. A discrimination based on a dimension or cue in modality is transferred to the same modality using the same dimension or cue.

Inspection stimulus. A stimulus having characteristic dimensions which the subject is required to retain and use as a basis for making decisions of equivalence in the same or different modalities.

Response choices. Multiple choice stimuli exposed, following the inspection stimulus, from which the subject must make decisions regarding equivalence; these may be presented in same or different modalities than the inspection stimulus.

Simultaneous processing. Information presented to the subject is organized into a spatial array by an unidentified cerebral mechanism at points of neural integration.

Successive processing. Information presented to the subject is sequentially organized by some unidentified cerebral mechanism at points of neural integration.

Sensory integration. The unidentified process of synthesis which makes a transfer across sensory modes possible. Assumes equivalence between modes.

Modality congruence. A term describing the relationship of modalities to stimulus distributions. A current viewpoint suggests that the visual modality is specialized for spatial distributions of stimuli and the auditory and tactile modalities are congruent with temporal distributions of stimuli.

Independent Variables.

Simultaneous condition. Stimuli are presented concurrently in a spatial array. Parallel stimuli are simultaneously surveyable (coding dimension of space).

Successive condition. Stimuli are presented in discrete temporal units. Sequential stimuli are part of a serial order and can only be inspected for the duration of the exposure of each unit.

Sensory modalities. Touch, vision, audition, taste and smell. Only the first three will be dealt with in this thesis.

Visual-simultaneous. A pattern of stimuli presented in a spatial array (concurrently in time), to be perceived by the visual receptors.

Visual-successive. A pattern of stimuli presented in a temporal arrangement (discretely in time), to be perceived by the visual receptors.

Tactual-simultaneous. A pattern of stimuli presented in a spatial array (concurrently in time), to be perceived by the tactual receptors.

Tactual-successive. A pattern of stimuli presented in a temporal arrangement (discretely in time) to be perceived by the tactual receptors.

Auditory-successive. A pattern of stimuli presented in a temporal arrangement (discretely in time), to be perceived by the auditory receptors.

Hypotheses

Rationale 1. There are, in the literature, some significant studies which propose that success on tasks requiring the processing of simultaneous and successive stimuli is probably related to the frequency with which individuals are exposed to these sorts of sensory information.

The basis for this notion derives from results indicating that the deaf, a population of subjects that are restricted in one modality of input, tend to perform less well than their hearing counterparts on tasks involving sequential presentations of stimuli. Furth (1966) suggests the possibility that linguistic practice provides the experience which would explain the superiority of hearing subjects on such tasks. In Furth's 1966 study comparing aphasic, deaf and hearing subjects on visual-simultaneous, visual-successive and auditory-successive tasks, he found that the younger deaf subjects performed more poorly than the normal control group on the successive sequence tasks but that these same children performed as well on the simultaneous presentation of sequences. He noted that, "In this study, contrary to the former one, simultaneous presentation was generally somewhat easier than successive presentation [p. 449]." This study also revealed that older subjects (10- and 11-year olds) performed as adequately as their hearing peers on the successive tasks. Intensive training in linguistic skills was believed to account for the improvement of the older subjects and the evidence that the younger hearing children ". . . found auditory sequence easier than visual sequence . . . [p. 448]." The lesson of the study is perhaps most clearly revealed in the following statement: ". . . the poorer performance on sequential tasks can be attributed to early deafness or linguistic deficiency in general . . . [p. 447]."

Hermelin and O'Connor (1964) furnish similar proof regarding the experiential factor in the processing of information. They discuss the necessity for more frequent tactile presentations in order to form stable images of the stimuli which would thus facilitate transfer from that modality to another.

We are again reminded of the experiential factor concerning the processing of information when we refer to Paivio's (1971) observation that the verbal system is specialized for the processing of temporal stimuli while visual perception is specialized for parallel processing of spatial stimuli.

Hypothesis 1. The evidence provided by Furth, Hermelin and O'Connor and Paivio suggest that the majority of the pre-lingually deafened population, who by their sensory deficit are less frequently exposed to the temporal stimuli provided by the verbal system, will do less well on tasks requiring the processing of temporally distributed stimuli than hearing control subjects. One might expect that they would produce more correct responses on tasks requiring transfers from and to visual-successive stimuli than those requiring transfers from and to tactual-successive and auditory-successive stimuli since the visual modality is a more familiar one.

1.1. Hearing subjects will produce more total correct responses than deaf subjects on all successive tasks.

1.2. Deaf subjects will produce more total correct responses on transfers to successive response choices in the visual mode than in the tactual and auditory modalities.

1.3. The data should indicate a learning trend for deaf subjects on all transfer tasks due to the subjects' ability to improve on these tasks as a result of experience with the task.

Rationale 2. The viewpoint which states that spatial and temporal distribution of stimuli tend to be specialized for, or more easily apprehended through certain sensory modalities, suggests that the relationship between sensory modalities and distributions is worth examination. If it is assumed that O'Connor and Hermelin (1971) are correct when they say that subjects "switch in" to the coding distribution congruent with a particular modality of presentation (e.g., visual-spatial/simultaneous), then we might also suspect that subjects will have more difficulty transferring to another distribution of stimuli that is not congruent with that modality (e.g., visual-temporal/successive) especially when that dimension is one in which they lack experience (e.g., deaf lack experience in successive processing). We might also expect that since the visual modality is the primary modality of input for the deaf (see Rationale for Hypothesis 1.) that the preferred mode and distribution for processing are the visual and spatial/simultaneous ones, or that they ". . . would dominate sensory organization in a precipient [Hermelin & O'Connor, 1971, p. 6]." We could anticipate that deaf subjects would perform best on the transfer which involves their preferred modality coupled with the stimulus distribution specific to it.

Hypothesis 2. Both deaf and hearing subjects will produce more total correct responses on tasks involving transfers to and from modality-congruent stimulus distributions than modality-incongruent stimulus distributions; subjects who have experience with a condition of a modality-incongruent stimulus distribution will produce more correct responses than subjects lacking such experience.

2.1. Both deaf and hearing subjects will produce more total correct responses on transfers from visual-simultaneous to visual-simultaneous than from visual-simultaneous to visual-successive distributions.

2.2. Both deaf and hearing subjects will produce more total correct responses on transfers from visual-simultaneous to tactual-successive than from visual-simultaneous to tactual-simultaneous distributions.

2.3. Both deaf and hearing subjects will produce more total correct responses on transfers from tactual-successive to tactual-successive than from tactual-successive to tactual-simultaneous distributions.

2.4. Both deaf and hearing subjects will produce more total correct responses on transfers from tactual-successive to visual-simultaneous than from tactual-successive to visual-successive distributions.

2.5. Both deaf and hearing subjects will produce more total correct responses on transfers from tactual-successive to auditory-successive than from tactual-successive to tactual-simultaneous distributions.

2.6. Both deaf and hearing subjects will produce more total correct responses on transfers from visual-successive to Visual-simultaneous than from visual-successive to tactual-simultaneous distributions.

2.7. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to auditory-successive distributions.

2.8. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to tactual-successive distributions.

2.9. Hearing subjects will produce more total correct responses than deaf subjects on transfers from tactual-successive to visual-successive distributions.

2.10. Hearing subjects will produce more total correct responses than deaf subjects on transfers from tactual-successive to auditory-successive distributions.

2.11. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to visual-successive distributions.

2.12. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to auditory-successive distributions.

2.13. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to tactual-successive distributions.

Rationale 3. It seems to be the case that animals, young hearing subjects, young deaf subjects and retarded readers all have greater difficulty than normal children in integrating stimuli from two or three different modalities; that is, cross-modal transfer (cf. review of the literature). This study attempts to determine where the difficulties lie; from and to which modalities are the difficulties most predominant for the deaf? On the basis of the experiential hypothesis referred to in the earlier rationale, requiring subjects to transfer from one modality to another, the hypothesis below is proposed.

Hypothesis 3. On tasks requiring subjects to perceive stimuli in one modality and to recognize the equivalent stimuli in a different modality, hearing subjects will produce more correct responses than deaf subjects.

3.1. Hearing subjects will produce more correct responses than deaf subjects on transfers from visual-simultaneous to auditory-successive distributions.

3.2. Hearing subjects will produce more correct responses than deaf subjects on transfers from visual-simultaneous to tactual-simultaneous distributions.

3.3. Hearing subjects will produce more correct responses than deaf subjects on transfers from visual-simultaneous to tactual-successive distributions.

3.4. Hearing subjects will produce more correct responses than deaf subjects on transfers from visual-successive to auditory-successive distributions.

3.5. Hearing subjects will produce more correct responses than deaf subjects on transfers from visual-successive to tactual-simultaneous distributions.

3.6. Hearing subjects will produce more correct responses than deaf subjects on transfers from visual-successive to tactual-successive distributions.

3.7. Hearing subjects will produce more correct responses than deaf subjects on transfers from tactual-successive to visual-simultaneous distributions.

3.8. Hearing subjects will produce more correct responses than deaf subjects on transfers from tactual-successive to visual-successive distributions.

3.9. Hearing subjects will produce more correct responses than deaf subjects on transfers from tactual-successive to auditory-successive distributions.

CHAPTER IV

METHOD

Sample

The sample consisted of 72 children from three different schools in the Edmonton area. Deaf and hearing children comprised the two populations of comparison. Ages of children ranged between eight and eighteen years; a relatively broad age range resulted due to the limitations presented by the availability of deaf subjects for testing and ability of these subjects to comprehend instructions.

Thirty-six deaf subjects were drawn from the Alberta School for the Deaf. Students were chosen on the basis of a severe to profound degree of hearing loss (60 db. loss +) and onset of deafness (pre-lingually and/or congenitally deafened). An additional criterion of selection was the ability to retain at least three units of information presented visually. Retention was determined by responses to a modified version of the Hiskey-Nebraska Memory Test for Colors for younger subjects; a modified version of the Hiskey-Nebraska Test for Numbers was used for older subjects. Based on results obtained with this screening device, subjects below the age of eight were not included in the sample. Subjects selected for testing were then randomly assigned to one of three groups and tested in a random order determined by their availability to researchers. Subjects included both residential and day students and represented all socioeconomic levels. The testing of all deaf subjects was conducted at the Alberta School for the Deaf.

Thirty-six hearing subjects were randomly selected from two Edmonton public schools chosen on the basis of their proximity to the University where the testing took place. The only criteria determining the participation of these subjects were age and the consideration that they were of normal abilities. As nearly as possible, hearing subjects were matched in age to the deaf subjects.

Deaf subjects were randomly assigned to one of three different groups described by the nature of the stimulus presentation. Hearing subjects were assigned to the same groups as their age-mate counterparts.

Deaf children ranged in age from 8 years, 6 months, to 18 years, 9 months. Mean age for the deaf subjects was 12 years, 5 months. Hearing children ranged in age from 8 years, to 18 years, 1 month. Mean age for this group was 13 years, 5 months (see Table 1).

Following testing, the results of six subjects were discarded because three deaf subjects were administered tactual-successive response choices in lieu of auditory-successive choices when it was determined that they were

TABLE 1

SUBJECTS DESCRIBED BY SEX AND CHRONOLOGICAL AGE

Group	Condition	Sex		Age Range	Mean Chronological Age
		Male	Female		
DEAF	VIS-SIM	8	3	8 years 6 months to 18 years 9 months	12 years 5 months
	VIS-SUC	6	5		
	TAC-SUC	4	7		
HEARING	VIS-SIM	6	5	8 years to 18 years 1 month	13 years 5 months
	VIS-SUC	6	5		
	TAC-SUC	4	7		

unable to hear the buzzes. The results of their yoked controls were deleted from the sample as well. This left a remainder of 66 subjects in the final analysis.

Design

The design of this investigation is presented in Figure 3, showing a breakdown of groups and conditions. As can be seen in the Figure, two groups of subjects varying in degree of hearing loss--none or profound--were employed. Also, three conditions of stimulus presentation were used: visual-simultaneous, visual-successive and tactual-successive. The response choice modality was varied as a within-subject variable consisting of five levels: visual-simultaneous, visual-successive, auditory-successive, tactual-successive and tactual-simultaneous. Specific hypotheses were tested by comparing cells across groups or conditions within a group or condition, as determined by the predicted effects of the hypotheses.

Apparatus

Eight different apparatus components were involved in carrying out the entire experiment, but only six were displayed to any subject. The components were arranged in a square configuration such that the subject was seated in the center (see Figure 4).

Inspection stimuli in the visual modes were situated directly in front of the subject on a table

INSPECTION STIMULI

RESPONSE CHOICES

		Visual-simultaneous	Visual-successive	Auditory-successive	Tactual-successive	Tactual-simultaneous
DEAF	Visual-simultaneous					
	Visual-successive					
	Tactual-successive					

RESPONSE CHOICES

		Visual-simultaneous	Visual-successive	Auditory-successive	Tactual-successive	Tactual-simultaneous
HEARING	Visual-simultaneous					
	Visual-successive					
	Tactual-successive					

Fig. 3.--Design of the investigation.

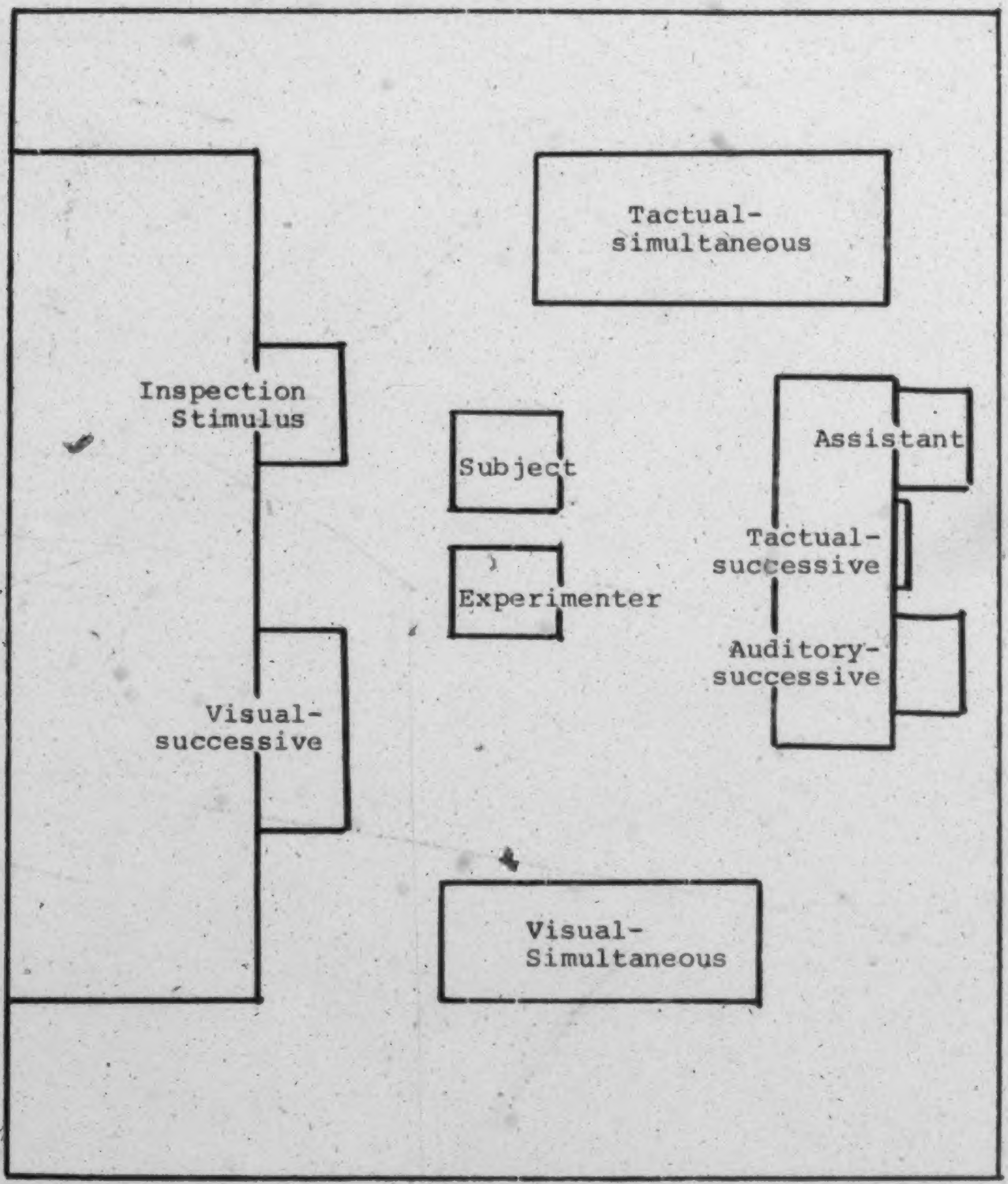
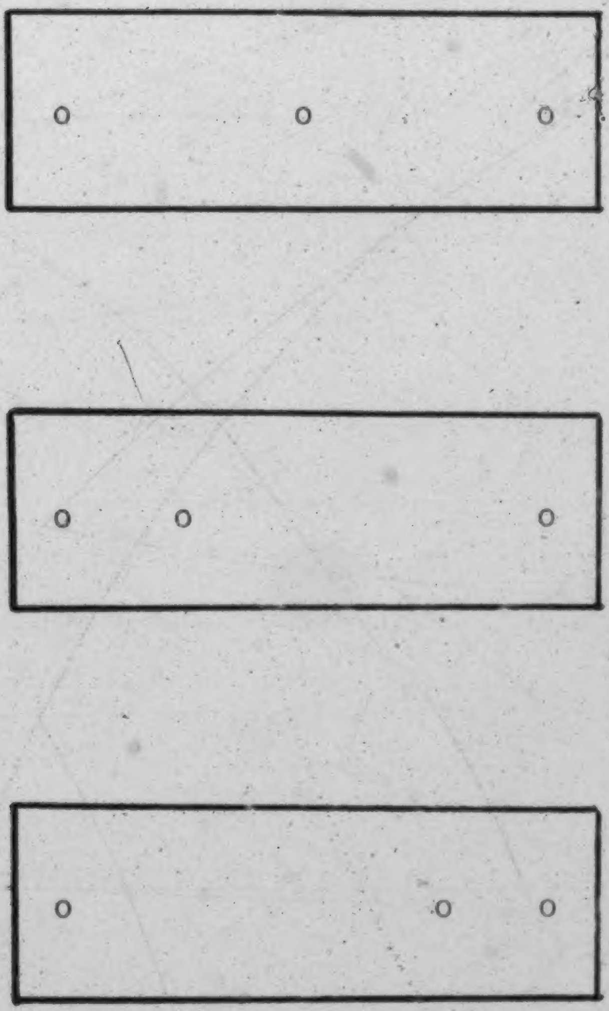


Fig. 4 .--Schematic view of apparatus.

29 1/2 inches high. Since a response choice apparatus was also on this table, inspection stimuli were always elevated to a position above the choice stimulus (12 inches above the table).

(1) Visual-simultaneous inspection stimulus apparatus consisted of a black felt board 9 by 22 inches. White felt dots, 3 inches in diameter, were positioned on the felt board in a horizontal arrangement. These dots were easily manipulated by the experimenter so that presentations could be varied throughout the course of testing (see Figure 5).

(2) For those subjects who were exposed to a visual-successive inspection stimulus, the felt board was removed from the table and replaced by a light bulb apparatus. This 40-watt blue bulb, fitted into a fixture with wiring threaded through a 3 1/2- by 11-inch wooden board, was controlled remotely by the assistant who was seated behind the subject (control box 8 by 5 inches). Flashes of light were varied according to the frequency and duration of the switch-pressing. All of the light bulbs used in the experiment were blue in color so that the subjects would have no difficulty distinguishing the stimuli from the white light in the room. Forty watts seemed to be a comfortable magnitude at which to perceive the stimuli, based on pilot testing.



Rectangle=field
O=stimulus

Fig. 5.--Stimulus distribution used in presentations.

(3) When subjects were to be presented with a tactual-successive inspection stimulus, the table was cleared of all other inspection stimuli. The subject was then tapped on the back by the assistant who was seated behind him, with a 12-inch plastic hammer (see Figure 5c).

The five different Response Choices exposed to all subjects were displayed around the subject within the square configuration described in Figure 4.

(1) The visual-successive response choice component rested on the table described earlier. This apparatus consisted of three 40-watt bulbs each encased in fixtures which fitted into a 3 1/2- by 24-inch wooden base. Each bulb was labelled with an appropriate number: 1, 2 or 3 ("1" on the left, "2" in the center, "3" on the right). Wires 11 feet long stemming from each bulb were threaded through the base, meeting behind the subject at a control box having three corresponding switches. This allowed the assistant to control the frequency and duration of the lights remotely.

(2) The visual-simultaneous response choice apparatus was set on the wall to the left of the subject. This consisted of a large piece of cardboard 31 inches high, 22 inches in diameter, upon which were stapled three pieces of black felt. Stimuli consisted of white felt dots indentical to those used for the inspection stimulus. Response choices were labelled 1, 2 and 3 ("1" at the top,

"2" in the center, "3" at the bottom). A divided curtain suspended from a portable frame was 5 1/2 feet high and set 2 feet in front of the stimulus board. This allowed the experimenter to stand behind the curtain and change the order of stimuli throughout the testing. At prescribed times, the experimenter opened the curtain to expose the choice stimuli to the subject (see Figure 5).

(3) A third response choice component for auditory-successive choices consisted of a Beltone Model 10-D audiometer controlled by the assistant. The subject was fitted with earphones and fed buzzes of varying frequencies and durations at a decibel level that was comfortable and audible to whichever ear was superior. First, second and third response choices were distinguised by numbers held up before the subject, by the experimenter, prior to each presentation .

(4) Tactual-successive response choices were provided in the following manner. The subject was tapped on the back by the assistant who was seated behind him, with a 12-inch plastic hammer. They were distinguished from the inspection stimulus by numbers (1, 2 and 3) which were held up before the subject by the experimenter, prior to each presentation. Positioning of each presentation on the subject's back varied so that no confounding effects (such as pressure on one point of the body) would interfere with responses.

(5) The final component for tactual-simultaneous response choices consisted of a wooden frame 25 inches by 27 inches by 14 inches. The frame was elevated in its position facing the subject, declining in a diagonal towards its end. At both its top and front, the frame was covered by opaque curtains. This allowed the subject to extend both hands through the front curtain into the apparatus and move his hands from one response choice to another without seeing any of them. The top end of the apparatus was covered by another opaque curtain which was easily lifted to allow the experimenter to put head and hands beneath the curtain and periodically change the order of the response choices. Each choice was numbered on the curtain above it ("1" nearest to subject, "2" in the center, "3" at the far end).

Description of Stimulus Materials

The experiment consisted of nine different kinds of inspection stimuli including all presentations for all groups; three different kinds for each subject. Inspection and response choice stimuli varied according to (a) modality of input (visual, auditory or tactual), (b) condition (simultaneous or successive) and (c) pattern (frequency or spatial distribution) of exposures.

Basically there were three possible patterns represented visually and spatially here:

(1) . . .

(2) .. .

(3) . ..

(1) The felt dots used in the visual-simultaneous presentation were 3 inches in diameter and distributed 5 inches apart in a configuration such as (1) above. In the second pattern the first two dots were 1 inch apart with 9 inches between the second and third dot. The third pattern had 9 inches between the first and second dots and 1 inch between the second and third. These measurements were the same for both simultaneous inspection and response choice stimuli. The visual-simultaneous inspection stimulus was exposed for 7 seconds. Response choice exposures remained displayed until the subject indicated that he had made his choice.

(2) The visual-successive inspection and response choice stimuli, which consisted of 40-watt blue light bulbs (8 inches between bulbs in response choice), displayed a pattern by means of a temporal distribution of flashes. The assistant counted out a succession of numbers by thousands. Pattern (1) above was counted in the following manner: the experimenter silently counted "One thousand one, one thousand two, one thousand three, one thousand four, one thousand five, one thousand six, one thousand seven." It took approximately one second to count each number, and lights were flashed at the counts of 1,001; 1,004 and

1,007. Therefore, pattern (1) was exposed for 7 seconds. Pattern (2) could be represented by the experimenter's counting between 1,001 and 1,006; flashing the light at the counts of 1,001; 1,003 and 1,006. Pattern (2) thus took 6 seconds to expose. For pattern (3) lights were flashed at the counts of 1,001; 1,004 and 1,006; as the experimenter counted between 1,001 and 1,006. Both inspection stimulus and response choice stimuli of a visual-successive nature were exposed in this manner.

(3), (4) Similarly, tactual-successive (inspection stimuli and response choices) and auditory-successive (inspection stimuli and response choices) were presented to the subject. For deaf subjects, the decibel level was always above the speech threshold; for hearing subjects 25 db. was standard.

(5) The tactual-simultaneous patterns were spatially distributed in the following manner:

(a) Pattern (1)
(b) Pattern (2)
(c) Pattern (3)

Wooden knobs were 2 inches in diameter and distributed on three masonite boards, 7 inches by 25 inches, each of which fit into the base of the apparatus. The choices were efficiently varied by simply lifting the boards by their knobs and placing them in their appropriate slot. Distributions were all determined in pilot testing.

Description of Task

The experimental treatments. Essentially, the testing consisted of three different tasks ([a] visual-simultaneous, [b] visual-successive and [c] tactual-successive) involving three different groups of subjects. All tasks involved transfer from an inspection stimulus of a particular mode and condition to five different response choices. Each response choice was repeated six times bringing the total number of trials for each subject to 30. Transfer occurred both intra-modally and cross-modally, depending on the nature of the inspection stimulus and the response choice. In all cases, the order of the response choices was randomly alternated to control for order effect.

Task (a). Subjects receiving this task were shown a visual-simultaneous inspection and required transfer to visual-simultaneous, visual-successive, tactual-simultaneous, tactual-successive and auditory-successive response choices. The only memory load was in the order of the three items of the inspection stimulus. Subjects were required to retain the stimulus arrangement and match this to the three response choices until a decision of match was derived. Following all three response choices, subjects indicated to the experimenter the response that matched the inspection stimulus, by responding "One," "Two," or "Three." The three possible arrangements for inspection stimuli were randomized so that not more than three of the same occurred in succession. The subjects were expected to respond for 30 trials of this task.

Task (b). All subjects involved in this task received a visual-successive inspection stimulus and were required to transfer to visual-simultaneous, visual-successive, tactual-simultaneous, tactual-successive and auditory-successive response choices. Subjects were required to retain the stimulus arrangement and match this to the three response choices until a decision of match was derived. Following all three response choices, subjects indicated to the experimenter, the response that matched the insepction stimulus, by responding "One," "Two," or "Three." The subjects were expected to respond for the 30 trials presented.

Task (c). Subjects received a tactual-successive stimulus on each trial. This was followed by visual-simultaneous, visual-successive, tactual-simultaneous, tactual-successive and auditory-successive response choices presented over 30 trials in a random order. Subjects were required to retain the stimulus arrangement and match this to the three response choices until a decision of match was derived. Following all three response choices, subjects indicated to the experimenter the response that matched the inspection stimulus, by responding "One," "Two," or "Three."

Procedure

All deaf subjects were tested in the same room at the Alberta School for the Deaf, since the residential students come from parts of the Province other than Edmonton and would not be available on weekends. Subjects were easily removed from their dormitories for the testing and thus more accessible to the experimenter. Hearing subjects were tested in a room at the University of Alberta, which was more accessible by public transportation than the Alberta School for the Deaf.

Prior to each task all subjects were given instructions by the experimenter. Although the instructions were conveyed verbally for hearing subjects and manually for deaf subjects, both were accompanied by demonstration using the apparatus and samples of task procedure. Equivalence of modalities and conditions of presentation was demonstrated by the experimenter in the following manner: (a) Subjects were first introduced to the apparatus by a short demonstration of how each part would function in the testing. (b) The experimenter next held a closed fist in front of the light bulb component, opening the fist and extending the fingers outward when the bulb was flashed, thus indicating the "flash" to deaf subjects. Hearing subjects were told the word "flash" verbally. (c) A pause (temporal delay in flash) between the second and third flash was indicated by the manual sign "wait" for deaf subjects; the verbal word "pause" for hearing subjects. (d) Subjects were next shown the three visual-simultaneous response choices and were directed to focus on the choice that was equivalent to the inspection stimulus. The experimenter then repeated the earlier demonstration: "Flash, flash, wait (pause), flash." But at the point of "wait (pause)" the experimenter's two hands were separated in a horizontal movement across the blank space and accompanying this gesture with the sign "wait" for the deaf, and the verbal "pause" for the hearing, thus equivocating the temporal dimension of non-flashing to the negative spatial dimension. The experimenter then told the subjects that the inspection stimulus and that particular response choice were the same; that the other two response choices differed from the inspection stimulus. The subject was asked if he understood. If he responded in the negative, the demonstration was repeated a maximum of two more times until the subject indicated an understanding. Subjects who did not understand the final explanation were stopped and did not participate in the rest of the experiment. Six deaf subjects were dropped during testing. All hearing subjects participated throughout all the testing.

Following the demonstration the experimental trials were begun. Each subject was asked to attend to the inspection stimulus and try to remember what he saw and find the one that was the same among the response choices, indicating to the experimenter whether this was number one, two or three. No strategy for remembering the stimulus was offered. Prior to each trial subjects were told that they should attend first to the inspection stimulus and then to the part of the apparatus involved in that particular trial.

The subject was then presented with the 30 trials. He was given feedback only during the demonstration; in all other cases the experimenter responded with "Okay," or repeated the response choice number to indicate that she had received the subject's decision and would go on.

Recording of Data

Data were recorded during the course of testing by the experimenter. This was done by observing (in the case of the deaf subjects) the response (one, two or three) of the subject, or listening (in the case of the hearing subjects) to the subject's response and placing a check-mark on the data recording sheet next to the response that corresponded to that of the subject. A copy of the data recording sheet is provided in Appendix A.

Scoring

Scoring was done by hand after all the data had been collected. Each response choice was matched to the inspection stimulus presented for each trial and data were collated across experimental conditions.

CHAPTER V

RESULTS

The results of the experimental investigation were analyzed according to the specific hypothesis presented previously in Chapter III. In order to assess these hypothesized effects the t test and analysis of variance techniques (Glass & Stanley, 1970, pp. 292-445) were employed. Table 2 presents the general design of the investigation, a 2 x 3 x 5 factorial design with the third variable being within-subject, along with the means and standard deviations for correct matching responses on the experimental task (see Table 2). This table portrays the conditions for inspection stimulus modality and response choice modalities which were contrasted in the hypothesized comparisons. The tests of each hypothesis will make reference to the comparisons as the conditions are presented in this table.

Hypothesis 1

The first hypothesis predicted that hearing subjects would produce more correct responses than their deaf counterparts on tasks which involved stimulus presentation in a modality (auditory or tactual) or condition (successive presentation) in which they lacked experience.

The specific predictions follow. They are quoted as they appear in Chapter III.

> Hypothesis 1.1. Hearing subjects will produce more total correct responses than deaf subjects on all successive tasks.

In order to test this hypothesis, hearing subjects were compared to deaf subjects on a composite mean score of all cells in Table 2 except the visual-simultaneous to visual-simultaneous and visual-simultaneous to tactual-simultaneous conditions. The t test for independent samples was employed indicating a significant difference between the two groups ($\bar{X}$ Hearing=23.42, $\bar{X}$ Deaf=18.79, t=3.20, df=32) at the .001 level. The results thus support the hypothesis in the predicted direction. A post-hoc analysis comparing the deaf and hearing subjects on the visual-simultaneous to visual-simultaneous transfer revealed no significant difference between the two groups on this condition ($\bar{X}$ Hearing=5.82, $\bar{X}$ Deaf=5.45, t=1.18, df=10, $p > .05$).

> Hypothesis 1.2. Deaf subjects will produce more total correct responses on successive response choices in the visual mode than in the tactual and auditory modalities.

This hypothesis was tested by comparing a composite score of the visual-successive response choice mode with the composite of the six cells in the tactual and auditory-successive response choice modes. A t test for dependent samples was employed which indicated a significant difference between the groups ($\bar{X}$ visual-successive=4.48, $\bar{X}$ auditory-successive and tactual-successive=4.09,

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR TOTAL CORRECT MATCHING CHOICE RESPONSES FOR SIX TRIALS COMPARING HEARING SUBJECTS ON INSPECTION STIMULUS AND RESPONSE CHOICE MODES

Group	Inspection stimulus condition	Response Choice Conditions				
		Visual-simultaneous	Visual-successive	Auditory-successive	Tactual-successive	Tactual-simultaneous
Deaf children	Visual-simultaneous	5.45 (.82)	4.36 (1.86)	3.72 (1.49)	4.27 (1.62)	4.18 (1.40)
	Visual-successive	4.90 (1.22)	3.90 (1.87)	3.90 (1.45)	4.27 (1.19)	3.54 (1.51)
	Tactual-successive	5.72 (.65)	5.18 (.75)	4.45 (1.57)	3.90 (1.38)	4.18 (1.25)
Hearing children	Visual-simultaneous	5.81 (.60)	5.54 (.93)	5.63 (.67)	5.81 (.40)	5.00 (1.22)
	Visual-successive	5.72 (.47)	5.45 (.69)	5.36 (.81)	5.09 (.70)	4.72 (1.01)
	Tactual-successive	5.45 (.69)	5.72 (.47)	5.45 (.69)	5.18 (1.25)	5.09 (1.14)

Note.--Numbers in parentheses are standard deviations.

t=1.79, df=32) at the .041 level. The results support the hypothesis in the predicted direction.

> Hypothesis 1.3. There should be a learning trend for the deaf on all transfer tasks due to the subjects' ability to improve on these tasks as a result of experience with the task.

This hypothesis was assessed with a one-factor, repeated measure, analysis of variance procedure in which the deaf subjects data were collapsed across both inspection stimulus and response choice conditions. In this analysis, the data were assessed across the six trials for each response choice condition which served as the six levels of the repeated measures. The means and standard deviations are presented in Table 3 for the six trial averages across these conditions. The analysis of variance revealed a significant difference between these trials (F=3.77, $df_1=5$, $df_2=300$) at the .01 level supporting the above hypothesis regarding an increase in accuracy of matching for the deaf subjects during the course of the experiment.

Summary of findings for Hypothesis 1. All three predictions in Hypothesis 1 were statistically significant. Hypothesis 1.1 was confirmed in that hearing subjects did significantly better than deaf subjects on all successive tasks. Hypothesis 1.2, which predicted that deaf subjects would produce more correct responses on successive tasks in the visual mode than in the tactual and auditory modes, was supported by the findings. Finally, Hypothesis 1.3, which predicted a learning trend for the deaf on all transfer tasks, was confirmed.

TABLE 3

MEANS FOR DEAF SUBJECTS FOR THE SIX TRIALS COLLAPSED ACROSS INSPECTION STIMULUS AND RESPONSE CHOICE CONDITIONS

Item	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Means	.642	.727	.739	.727	.770	.794
Standard Deviation	(.481)	(.447)	(.440)	(.447)	(.422)	(.410)

Hypothesis 2

The second hypothesis predicted first that deaf and hearing subjects would produce more correct responses on tasks involving transfers to and from modality-congruent stimulus distributions (e.g., visual-spatial and auditory-temporal) than modality-incongruent distributions; secondly that subjects who have experience with a condition of a modality-incongruent (e.g., visual-successive, tactual-simultaneous) stimulus distribution will produce more correct responses than subjects lacking such experience. The specific predictions follow, quoted from Chapter III.

> Hypothesis 2.1. Both deaf and hearing subjects will produce more total correct responses on transfers from visual-simultaneous to visual-simultaneous than from visual-simultaneous to visual-successive distributions.

A t test for dependent samples was performed for these two conditions which resulted in a significant difference ($\overline{X}$ visual-simultaneous to visual-simultaneous=5.64, $\overline{X}$ visual-simultaneous to visual-successive=4.95, t=2.06, df=21) at the .026 level. The results thus supported this hypothesis in the predicted direction.

> Hypothesis 2.2. Both deaf and hearing subjects will produce more total correct responses on transfers from visual-simultaneous to tactual-successive than from visual-simultaneous to tactual-simultaneous distributions.

A t test for dependent samples comparing these two conditions across both groups was performed. The results of the analysis ($\overline{X}$ visual-simultaneous to tactual-successive=5.05, $\bar{X}$ visual-simultaneous to tactual-simultaneous=4.59, t=1.36, df=21) do not support this hypothesis.

> *Hypothesis 2.3.* Both deaf and hearing subjects will produce more total correct responses on transfers from tactual-successive to tactual-successive than from tactual-successive to tactual-simultaneous distributions.

A *t* test for dependent samples was performed collapsed across both groups of subjects comparing these conditions. The results of the analysis do not support this hypothesis ($\bar{X}$ tactual-successive to tactual-successive=4.55, $\bar{X}$ tactual-successive to tactual-simultaneous=4.64, t=.34, df=21).

> *Hypothesis 2.4.* Both deaf and hearing subjects will produce more total correct responses on transfers from tactual-successive to visual-simultaneous than from tactual-successive to visual-successive distributions.

A *t* test for dependent samples was performed on these two conditions across both subject groups. The results of the analysis do not support this hypothesis ($\bar{X}$ tactual-successive to visual-simultaneous=5.59, $\bar{X}$ tactual-successive to visual-successive=5.45, t=.65, df=21).

> *Hypothesis 2.5.* Both deaf and hearing subjects will produce more total correct responses on transfers from tactual-successive to auditory-successive than from tactual-successive to tactual-simultaneous distributions.

A *t* test for dependent samples was performed comparing these conditions. The results of the analysis do not support this hypotheses ($\bar{X}$ tactual-successive to auditory-successive=4.95, $\bar{X}$ tactual-successive to tactual-simultaneous=4.64, t=.94, df=21).

> Hypothesis 2.6. Both deaf and hearing subjects will produce more correct responses on transfers from visual-successive to visual-simultaneous than from visual-successive to tactual-simultaneous distributions.

A t test for independent samples was performed which resulted in a significant difference ($\bar{X}$ visual-successive to visual-simultaneous=5.32, $\bar{X}$ visual-successive to tactual-simultaneous 4.59, t=2.08, df=21) at the .024 level. The results thus supported this hypothesis in the predicted direction.

> Hypothesis 2.7. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to auditory-successive distributions.

A t test for independent samples was performed comparing these groups which resulted in a significant difference ($\bar{X}$ Hearing=5.64, $\bar{X}$ Deaf=3.73, t=3.87, df=10) at the .001 level. The results supported this hypothesis in the predicted direction.

> Hypothesis 2.8. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to tactual-successive distributions.

A t test for independent samples was performed between the groups which resulted in a significant difference ($\bar{X}$ Hearing=5.82, $\bar{X}$ Deaf=4.27, t=3.07, df=10) at the .005 level. The results thus supported this hypothesis in the predicted direction.

> Hypothesis 2.9. Hearing subjects will produce more total correct responses than deaf subjects on transfers from tactual-successive to visual-successive distributions.

A *t* test for independent samples was performed for this comparison which resulted in a significant difference ($\bar{X}$ Hearing=5.73, $\bar{X}$ Deaf=5.18, t=2.05, df=10) at the .033 level. The results thus supported this hypothesis in the predicted direction.

> Hypothesis 2.10. Hearing subjects will produce more total correct responses than deaf subjects on transfers from tactual-successive to auditory-successive distributions.

A t test for independent samples was performed on these conditions which resulted in a significant difference ($\bar{X}$ Hearing=5.45, $\bar{X}$ Deaf=4.45, t=1.93, df=10) at the .041 level. The results thus supported this hypothesis in the predicted direction.

> Hypothesis 2.11. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to visual-successive distributions.

A t test for independent samples was performed between these groups which resulted in a significant difference ($\bar{X}$ Hearing=5.45, $\bar{X}$ Deaf=3.91, t=2.57, df=10) at the .013 level. The results supported this hypothesis in the predicted direction.

> Hypothesis 2.12. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to auditory-successive distributions.

A *t* test for independent samples was performed which resulted in a significant difference ($\bar{X}$ Hearing=5.36,

$\overline{X}$ Deaf=3.91, t=2.91, df=10) at the .007 level. The results thus supported this hypothesis in the predicted direction.

> Hypothesis 2.13. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to tactual-successive distributions.

A t test for independent samples was performed between these groups which resulted in a significant difference ($\overline{X}$ Hearing=5.09, $\overline{X}$ Deaf 4.27, t=1.96, df=10) at the .038 level. The results thus supported this hypothesis in the predicted direction.

Summary of findings for Hypothesis 2. The first part of the second hypothesis (Hypotheses 2.1 through 2.5) which stated that both deaf and hearing subjects would produce more correct responses on tasks involving transfers to and from modality-incongruent stimulus distributions was generally not supported by the results. Hypothesis 2.1, however, was confirmed in that both deaf and hearing subjects performed significantly better on transfers from visual-simultaneous to visual-simultaneous stimulus distributions than on transfers from visual-simultaneous to visual-successive stimulus distributions. The second part of Hypothesis 2 (Hypotheses 2.6 through 2.13) which stated that subjects who have experience with a condition of a modality-incongruent stimulus distribtuion would produce more correct responses than those who do not have such experience, was confirmed in each comparison.

Hypothesis 3

The third hypothesis predicted that on tasks requiring subjects to perceive stimuli in one modality and recognize the equivalent stimuli in a different modality, hearing subjects would show more accurate coding than deaf subjects. Table 4 shows the specific comparisons for each of these cross-modal transfers. The specific hypotheses, quoted from Chapter III, are assessed below.

> Hypothesis 3.1. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to auditory-successive distributions.

A t test for independent samples was performed for these groups which resulted in a significant difference ($\bar{X}$ Hearing=5.64, $\bar{X}$ Deaf=3.73, t=3.87, df=10) at the .001 level. The results thus supported the hypothesis in the predicted direction.

> Hypothesis 3.2. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to tactual-simultaneous distributions.

A t test for independent samples was performed for these groups. The results of the analysis do not support this hypothesis ($\bar{X}$ Hearing=5.00, $\bar{X}$ Deaf=4.18, t=1.44, df=10).

> Hypothesis 3.3. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-simultaneous to tactual-successive distributions.

A t test for independent samples was performed for these groups which resulted in a significant difference ($\bar{X}$ Hearing=5.82, $\bar{X}$ Deaf=4.27, t=3.07, df=10) at the .005

level. The results thus supported this hypothesis in the predicted direction.

> *Hypothesis 3.4*. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to auditory-successive distributions.

A *t* test for independent samples was performed which resulted in a significant difference ($\bar{X}$ Hearing=5.36, $\bar{X}$ Deaf=3.91, t=2.91, df=10) at the .007 level. The results thus supported this hypothesis in the predicted direction.

> *Hypothesis 3.5*. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to tactual-simultaneous distributions.

A *t* test for independent samples was performed for these groups which resulted in a significant difference ($\bar{X}$ Hearing=4.73, $\bar{X}$ Deaf=3.55, t=2.16, df=10) at the .028 level. The results thus supported this hypothesis in the predicted direction.

> *Hypothesis 3.6*. Hearing subjects will produce more total correct responses than deaf subjects on transfers from visual-successive to tactual-successive distributions.

A *t* test for independent samples was performed between those groups which resulted in a significant difference ($\bar{X}$ Hearing=5.09, $\bar{X}$ Deaf=4.27, t=1.96, df=10) at the .038 level. The results thus supported this hypothesis in the predicted direction.

> *Hypothesis 3.7*. Hearing subjects will produce more total correct responses than deaf subjects on transfers from tactual-successive to visual-simultaneous distributions.

TABLE 4

COMPARISON OF DEAF AND HEARING SUBJECTS ON VARIOUS CROSS-MODAL TRANSFERS

Transfer	Deaf Mean	Pooled s	Hearing Mean	t Value	df	p
Visual-simultaneous to Auditory-successive	3.72	1.15	5.63	3.87	10	.001
Visual-simultaneous to Tactual-simultaneous	4.18	1.33	5.00	1.43	10	.09
Visual-simultaneous to Tactual-successive	4.27	1.17	5.81	3.07	10	.005
Visual-successive to Auditory-successive	3.90	1.17	5.36	2.91	10	.007
Visual-successive to Tactual-simultaneous	3.54	1.28	4.72	2.16	10	.028
Visual-successive to Tactual-successive	4.27	.977	5.09	1.96	10	.038
Tactual-successive to Visual-simultaneous	5.72	.667	5.45	.95	10	.180
Tactual-successive to Visual-successive	5.18	.625	5.72	2.04	10	.033
Tactual-successive to Auditory-successive	4.45	1.21	5.45	1.93	10	.041

A t test for independent samples was performed between these groups. The results of the analysis do not support this hypothesis ($\overline{X}$ Hearing=5.45, $\overline{X}$ Deaf=5.73, t=.96, df=10).

> Hypothesis 3.8. Hearing subjects will produce more correct responses than deaf subjects on transfers from tactual-successive to visual-successive distributions.

A t test for independent samples was performed for these conditions which resulted in a significant difference ($\overline{X}$ Hearing=5.73, $\overline{X}$ Deaf=5.18, t=2.05, df=10) at the .033 level. The results thus supported the hypothesis in the predicted direction.

> Hypothesis 3.9. Hearing subjects will produce more total correct responses than deaf subjects on transfers from tactual-successive to auditory-successive distributions.

A t test for independent samples was performed which resulted in a significant difference ($\overline{X}$ Hearing=5.45, $\overline{X}$ Deaf=4.45, t=1.93, df=10) at the .041 level. The results thus supported this hypothesis in the predicted direction.

Summary of findings for Hypothesis 3. This hypothesis (Hypotheses 3.1 through 3.9) was generally supported by the results in that in all but two comparisons the hearing subjects produced significantly more correct responses on cross-modal transfers than the deaf subjects. Hypothesis 3.2 which predicted that hearing subjects would perform in a manner superior to deaf subjects on transfers from visual-simultaneous to tactual-simultaneous stimulus distributions and Hypothesis 3.7 which predicted that hearing subjects would produce more correct responses on transfers from tactual-successive to visual-simultaneous stimulus distributions were not confirmed by the results, i.e., no significant differences were revealed.

CHAPTER VI

DISCUSSION

The Hypotheses

Hypothesis 1. The underlying assumption of this study was that perceptual processes for hearing and deaf children would differ only in those areas of processing where the deaf are restricted in perceptual experiences that are available to the hearing. It was proposed in Hypothesis 1 that the deaf and hearing subjects' responses to the stimulus materials in the various conditions would vary relative to their experience with processing analogous material. Since it is the case that experience with successive processing is gained primarily through the auditory modality, it was predicted that hearing subjects produce more correct responses than the deaf subjects on transfer tasks involving these successive conditions. The results of the subjects' performance on successive tasks which tested this prediction supported the first hypothesis in the predicted direction. The performance of hearing subjects was superior to that of the deaf subjects on successive tasks. This reasoning was extended to suggest that there would be no significant differences between the deaf and hearing on tasks involving modalities and conditions in which both groups were equally experienced. A post-hoc analysis revealed that indeed there were no significant differences between these groups on transfers from visual-simultaneous distributions to visual-simultaneous distributions. Further support for this hypothesis was evidenced in the results of Hypothesis 1.2, wherein deaf subjects produced significantly more correct responses on successive response choices in the visual mode than in the tactual and auditory modalities. In this instance an unfamiliar condition (successive) was associated with three different modalities and as predicted the deaf did significantly better on response choices in the visual-successive modality than in the tactual-successive and auditory-successive modality. These results indicated that the visual modality is one that for the deaf is superior to the others regardless of condition. From the above we can conclude that the modality with which the deaf have most experience is also the modality most suited for making decisions of equivalence in same or different modalities. The import of such results lies in the earlier analysis of the reading process and the search for an explanation of the high incidence of reading retardation among the deaf. A primary deficiency in successive processing would imply that the deaf would have difficulty in what Lashley (1960) has described as the hierarchy of integrations involved in the expression of language. Paivio's (1971) proposal that the verbal system is specialized for the processing of temporally organized patterns would suggest that inferior processing of successive stimuli would be cause for a disturbance in the verbal system. If we consider deaf children who are taught in a manner similar to hearing children, involving the transfer from and to successive stimuli, then the problems of the deaf, manifested in the form of reading retardation, could at least partially be explained by the fact that the deaf have difficulty with processing and transferring successive information. It is also evident that to teach the deaf in such a manner would be to least exploit the modality and condition in which they are most successful and most like their hearing peers--that is the visual-simultaneous modality and condition. The results appear to conclusively identify the visual-simultaneous to visual-simultaneous transfers and visual-simultaneous response choices as the strongest input and response modes for deaf recipients.

The results of the analysis for the third part of Hypothesis 1 revealed a learning trend over the six presentations in all conditions for the deaf subjects. These findings suggest that if we would attempt to teach students on tasks involving intersensory integration (language and reading for the deaf), repeated exposure to stimuli of that nature could probably enhance the effectiveness of training. As Shagan puts it, "The critical variable is not the modality per se but the degree of experience in working with a modality [Goodnow, 1971, p. 4]."

Hypothesis 2. The second hypothesis first predicted that deaf and hearing subjects would perform in a superior fashion on tasks involving modality-congruent stimulus distributions than to tasks involving modality-incongruent distributions. In general, this part of the hypothesis was not supported by the results. There were no significant differences between transfers that involved modality congruent conditions in comparison to modality-incongruent conditions. It appears that these results suggest only that modality-congruency will not necessarily simplify the problem of transfer. Although these results might lead one to suspect that simultaneous distributions are not necessarily apprehended most easily through through the visual modality and successive distributions are not perceived best by the auditory and tactual modalities as O'Connor and Hermelin have proposed (1971), caution should be heeded before arriving at such an interpretation. It is more probable that this study involved a procedure that was not an adequate test of this hypothesis. These findings suggest that it is likely that skill in learning to read and manipulate language symbols is dependent on perceiving stimuli through the most receptive modality but not necessarily the case that transfer from one modality to another is facilitated by modality congruency.

A second part of Hypothesis 2 predicted that the hearing subjects would produce more correct responses than the deaf subjects on transfers from and to modality-incongruent conditions in which the deaf lacked experience. This hypothesis was in all cases confirmed which lent further support to the notion that experience would facilitate transfer. That is, experience in both simultaneous and successive processing appears to be essential for the transfer from and to modality-incongruent stimuli. The deaf subjects, having a less substantial foundation of successive processing experiences appear to have greater difficulty than the hearing subjects in the transfer of successive information within a modality-incongruent context.

Hypothesis 3. The final hypothesis was supported in all but two instances. Based on responses of both deaf and hearing subjects on cross-modal as well as cross-condition transfer, results have shown that there are significant statistical differences between individuals whose sensory receptors are normal and those who experience a sensory deficit. Hearing subjects produced more correct responses on the following cross-modal and cross-condition transfers: visual-simultaneous to auditory-successive, visual-simultaneous to tactual-successive, visual-successive to auditory-successive, visual-successive to tactual-simultaneous, visual-successive to tactual-successive, tactual-successive to visual-successive and tactual-successive to auditory-successive.

Because language learning (in terms of competence and performance) for the deaf, is dependent on an ability to recognize as well as arrange patterns of stimuli into spatial and temporal arrangements, intra-modally and cross-modally, the support of Hypothesis 3 is a significant finding. On the task designed to test this hypothesis the deaf subjects demonstrated greater difficulty than hearing subjects, with the integration of stimuli received in one modality and one particular condition to be perceived in another or same modality and condition. The literature has evidenced that essential to linguistic and reading ability is a basic ability to code stimulus information across modalities and conditions. Inasmuch as reading is dependent on the ability to make judgements of auditory-visual equivalence and, "a primary disturbance in the ability to integrate stimuli from two critical sense modalities, hearing and vision, may well serve to increase the risk of becoming a poor reader [Birch & Belmont, 1964, p. 858]," the findings of the present study suggest that the poor intersensory performance by deaf subjects is at least in part a factor which can account for reading retardation among the deaf; this proposal would be the case when reading is taught to the deaf in an analogous fashion as it is taught to hearing children. Birch and Belmont (1964) have proposed that other factors may also account for reading incompetence; e.g., "emotional disturbances, cultural deprivation, disturbances in lateralization of function and other indicators of neurologic dysfunction . . . [p. 860]."

The failure to find support for two specific predictions, namely Hypothesis 3.2, which predicted that hearing subjects would produce more correct responses than deaf subjects on transfers from visual-simultaneous to tactual-simultaneous distributions, and Hypothesis 3.7, which predicted that hearing subjects would produce more correct responses than deaf subjects on transfers from tactual-successive to tactual-simultaneous distributions, might be explained by the fact that both deaf and hearing groups share equally in experience with visual-simultaneous distributions and inexperience with tactual-simultaneous and tactual-successive distributions of stimuli. The task of transferring from a modality-congruent inspection stimulus to a modality-incongruent response choice proved to be equally as difficult for both groups. The fact that in all other cases, response of the hearing subjects on transfer tasks were significantly better than those of the deaf, with the exception of these two, implies something of a paradigm for the viewpoint that sensory experience is related to sensory performance.

The results of this investigation have identified the inability of deaf children to process auditory-successive information as cause for differential responses at cross-modal transfer tasks between deaf and hearing groups. Although memory is a factor necessary for solving intersensory problems in a multiple-choice condition, which could contribute to the results, the design of the experiment controlled for the possible interference of the factor by prior testing of deaf subjects with the Hiskey Nebaska Memory Test of Colors and Numbers. It is not likely that the results obtained could be attributed to a deficiency in memory. Yet the possibility that subjects' memory for sensory stimuli in one modality is superior or inferior to their memory for sensory stimuli in another modality could account for the significant differences in response choices. Because this study has not attempted to determine causes for the differences found, but has attempted only to identify them, it would be of interest to explore the memory factor with the deaf in future research.

Some non-empirical observations made during the course of testing led the experimenter to believe that apart from differences between groups, differences among subjects could perhaps be accounted for by the coding strategies adopted by some subjects. Goodnow discusses this concept aptly in the following:

> Equally, the difficulty with cross-modal matching may lie in a tendency to use different forms of coding for different material. One has the feelings for example, that young children are more likely to use number coding for a series of dots on a page than for a series of sounds (they have learned to count with visual material). Older children, however, give the impression of being more likely to use number codings for both kinds of stimuli. Finally, the young child may have particular difficulty with some cross-modal tasks. . . because he lacks the rules that convert one stimulus pattern into another [Goodnow, 1971, p. 23].

The design of the experiment did not permit empirical testing of coding operations, but it was apparent that several deaf subjects adopted a manual strategy. In these cases the stimulus arrangement was manifested in the subjects' hands. For example, a spatial or temoral arrangement in which the stimulus was distributed such that two contiguous dots or beeps were separated by a spatial or temporal interval from a third, subjects raised two fingers on one hand and one finger on the other. This kind of strategy suggests a kind of manual mediation for the solving of transfer problems. Manual mediation seemed to have served as a short-term memory retainer for these deaf subjects. The utility of this observation lies in the possibility of initiating manual strategies in programs designed to train cross-modal transfer for the purpose of teaching language and reading to the deaf.

Implications

The implications of the study just described, generally lie in the area of education of the deaf;

specifically in the area of designing reading and language programs. One suggestion for an instructional option in this area is the use of sign language in teaching the deaf child to read.

Although it has been suggested earlier in this thesis that the existence of reading and language at all is an achievement for the deaf child taught by an oral method, the reader is directed to consider an alternative to reading retardation. If the oral approach to the teaching of reading is an overly complex procedure having unrealistic expectations, then an alternative would seem to be a simpler method of instruction.

A simpler method would involve placing the emphasis of language training on the visual mode and using spatially distributed stimuli. Accomplishing this would merely involve using sign language (a visual stimulus spatially distributed) as an input to be processed by the child. Obviously, we would want the child to respond and this would require cross-modal transfer. But cross-modal transfer would be to an equivalent condition; i.e., from visual stimuli spatially distributed, to motoric responses spatially distributed. Acquiring language and learning to communicate would involve merely learning units of spatially distributed information. Individual signs when combined into sentences could provide the child with experiences in serial ordering of meaningful units. Later, when the child enters school, reading may involve transfer across modalities, but conditions of presentation would remain the same. Reading would entail learning to recognize visual-spatial units (words) as associated with visual and motoric units (signs) and with other visual-spatial units (concrete objects). At the time of school entrance the deaf child would also have developed to the point of being receptive to cross-modal transfer problem-solving (Birch & Belmont, 1965). Successive processing should not be neglected. However, acquisition of successive processing, as the results have shown, is not a developmental phenomenon for deaf children. Successive processing should be formally trained before the child is expected to exercise it. A training procedure would best begin with successive processing in the visual modality and other modalities introduced following mastery.

While this suggested method of teaching reading to deaf children differs from that used to teach hearing children, the characteristic simplicity of the operations involved is similar. It is hoped that such an approach to instructing reading would result in a minimal incidence of reading retardation among the deaf.

Future research. The logical next step after the study presented in this thesis would be a study examining subjects' responses to a pre-test, training procedure and post-test set of tasks designed to measure the effects of training on successive processing (particularly in the visual modality). If deaf subjects, as predicted, improve on successive tasks following training, further evidence would exist for proposing that teachers of the deaf systematically provide such training in their educational programs.

Another suggestion for future research is a replication of Blank and Bridger's study (see the review of the literature, Chapter II) describing cross-modal equivalence and cross-modal concept utilizing deaf subjects. The results of their experiment supported the investigators' hypothesis which stated that language is not necessary for problems involving CME, but essential for CMC tasks. CME- and CMC-type tasks are implicit in programs designed to teach deaf children to speak. It would be of interest therefore, to conduct a similar experiment involving pre-school deaf children whose verbal experience is limited or negligible in hopes of determining whether or not (a) there is any indication that pre-school deaf children are prepared to begin language training that involves CMC tasks and (b) if the absence of an auditory language base inhibits successful performance of CMC problems.

A third suggestion for further research is to select deaf subjects so that there are an equal number of subjects in each in each age bracket. Developmental trends would thus become evident. Selection of subjects in the experiment described in this thesis was not made in this way due to the availability of subjects for testing.

Summary

The present study sought to investigate differences between two groups, one group comprised of hearing-impaired children and the other comprised of normal hearing children, based on their responses to various intramodal, cross-modal, intracondition and cross-condition tasks. In addition to differences between groups, the study attempted to determine (a) the optimal stimulus combination for the transfer of perceptual information for deaf subjects and (b) whether or not repeated exposure to tasks would result in improvement by deaf subjects.

The literature regarding simultaneous and successive information processing and cross-modal transfer suggested (a) that the sensory modalities at some level of cortical operation are equivalent which could account for the human ability to transfer perceptual information across modalities and (b) the fact that experience with simultaneous and successive stimulus distributions can be acquired in one modality and transferred to a different modality. It had been proposed that a hearing loss precludes the reception of auditory stimuli and would thus cause deaf children to have greater difficulty than hearing children in processing perceptual information of a successive nature. The implication of this suggestion is that the difficulties manifested by the hearing-impaired in linguistic and reading performance, when they are taught in a traditionally oral method, could be attributed to a basic deficiency in perceptual processing. It had been hypothesized that the hearing subjects involved in this study would demonstrate greater facility than deaf subjects at cross-modal, cross-condition, and modality-incongruent tasks but that deaf and hearing subjects would perform in a like manner on tasks involving stimuli which the subjects have experienced equally; i.e., visual-simultaneous to visual-simultaneous transfers.

Thirty-three deaf and 33 hearing subjects were randomly assigned to three different groups distinguished by inspection stimulus modality and condition: visual-simultaneous, visual-successive and tactual-successive. All subjects were administered tests involving the same five response choices: visual-simultaneous, visual-successive and tactual-simultaneous. The results indicated that there are significant differences between deaf and hearing subjects on cross-modal and modality-incongruent transfers but no difference on transfers from visual-simultaneous to visual-simultaneous stimulus distributions.

The deaf subjects made fewer correct responses on all successive tasks than hearing subjects. However, analysis of the responses made by deaf subjects revealed a learning trend for successive tasks. The findings thus provide general support for the hypothesis.

Although this study has primarily concentrated on establishing an understanding of the perceptual processes of the deaf and the relation of these processes to linguistic and reading competence, a more encompassing viewpoint should reveal profound but as yet abstrusive effects of a condition which prohibits individuals from regularly experiencing stimuli distributed in time. Visual and tactual stimuli can only serve to supplement the consequences of experiencing auditory stimuli if those who attempt to teach the deaf are prepared to provide their students with opportunities to experience visual-successive and tactual-successive stimuli as part of their educational schema.

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APPENDIX A

Instructions

The instructions to subjects, which follow, were signed to deaf subjects and spoken to hearing subjects.

"Hi, ----. My name is Barbara and this is my assistant, Patrick. We're going to play a little game. See all of these things around you? I'll tell you how they work. These are lights. See the flashes?"

Lights are flashed. Experimenter verbalizes or signs, "flash, flash, flash," with appropriate pauses between flashes. This arrangement was always used: flash-flash-pause-pause-flash.

"Now look over here."

Subject is directed to look at visual-simultaneous responses choices.

"See, there are three choices. You must find the one that is the same as the one I show you first."

Experimenter goes back to the lights and gives an example, then back to dots. Experimenter demonstrates manually or verbally that a particular temporal flashing arrangement is equivalent to the spatially distributed dot.

"They are same. 'Dot, space, dot, space, dot,' is the same as 'Flash, wait, flash, wait, flash.' Only one of these," (experimenter points to choices 1, 2 and 3) "will be the same as what you will see," (or "feel," depending on inspection-stimulus modality). "Two will be different, okay? Now turn around," (subject is directed to tactual-simultaneous response choice to his right). "Put your hands in here, but look on top. Can you feel the knobs? You see this part of the game has three choices as well. This is number one, number two and number three."

Experimenter directs subject's hands, from opposite end, to explore the stimulus.

"'Flash, wait, flash, wait, flash,' is the same as this," (as subject is directed to feel knobs and spaces between the knobs).

"Okay? Now look at me. Patrick will put earphones on your head. Are they comfortable? Raise your hand when you can hear something." Appropriate decibel level and frequency are determined.

"The buzzes are the same as the lights, the same as the dots, the same as the knobs." Experimenter repeats "Flash, wait, . . . etc.," manually while assistant relays buzzes.

"I will hold up these cards," (experimenter demonstrates by holding up cards with numbers, "1," "2" and "3") "and you will tell me which one is the same as what you will see," (or "feel") "first."

"Next, Pat will tap you on the back. Look at me. I will hold up these cards again and then Pat will tap you. The tapping is the same as the buzzes, the same as the knobs, the same as the dots, the same as the lights.

"Let's try the games."

Inspection stimulus is always given in a condition different than the one the subject will be presented with in the trials.

"Try to remember what you see," (demonstration).

"Now, which one is the same as what you saw? Do not give me an answer until you have seen" (or "heard" or "felt") "all three choices. Answer 'one,' 'two' or 'three.'

"That's right!" or "No, this is the correct answer." "Do you understand?"

If subject did not understand, a maximum of two more examples was given. If subject still did not understand, he was deleted from the sample.

APPENDIX B

Data Recording Sheet

SUBJECT________________ BIRTHDATE______________ AGE________

TRIALS	CODE 1	PRESENTATION STIMULUS MODE	CODE 2	RESPONSE CHOICES				
1				O	O			O
				O		O		O
				O			O	O
2				O	O			O
				O		O		O
				O			O	O
3				O	O			O
				O		O		O
				O			O	O
4				O	O			O
				O		O		O
				O			O	O
5				O	O			O
				O		O		O
				O			O	O
6				O	O			O
				O		O		O
				O			O	O
7				O	O			O
				O		O		O
				O			O	O